National Aeronautics and
Space Administration

Science Committee Report

Dr. Bradley M. Peterson
Chair, Science Committee

Science Committee Members

Brad Peterson, Chair, The Ohio State University
Carle Pieters, Vice Chair, Brown University

Janet Luhmann, UC Berkeley, Chair of Planetary Science Subcte
Steve Running, University of Montana, Chair of Earth Science Subcte
Scott Gaudi, The Ohio State University, Chair of Astrophysics Subcte
Robert Lindberg, University of Virginia, Chair of Planetary Protection Subcte

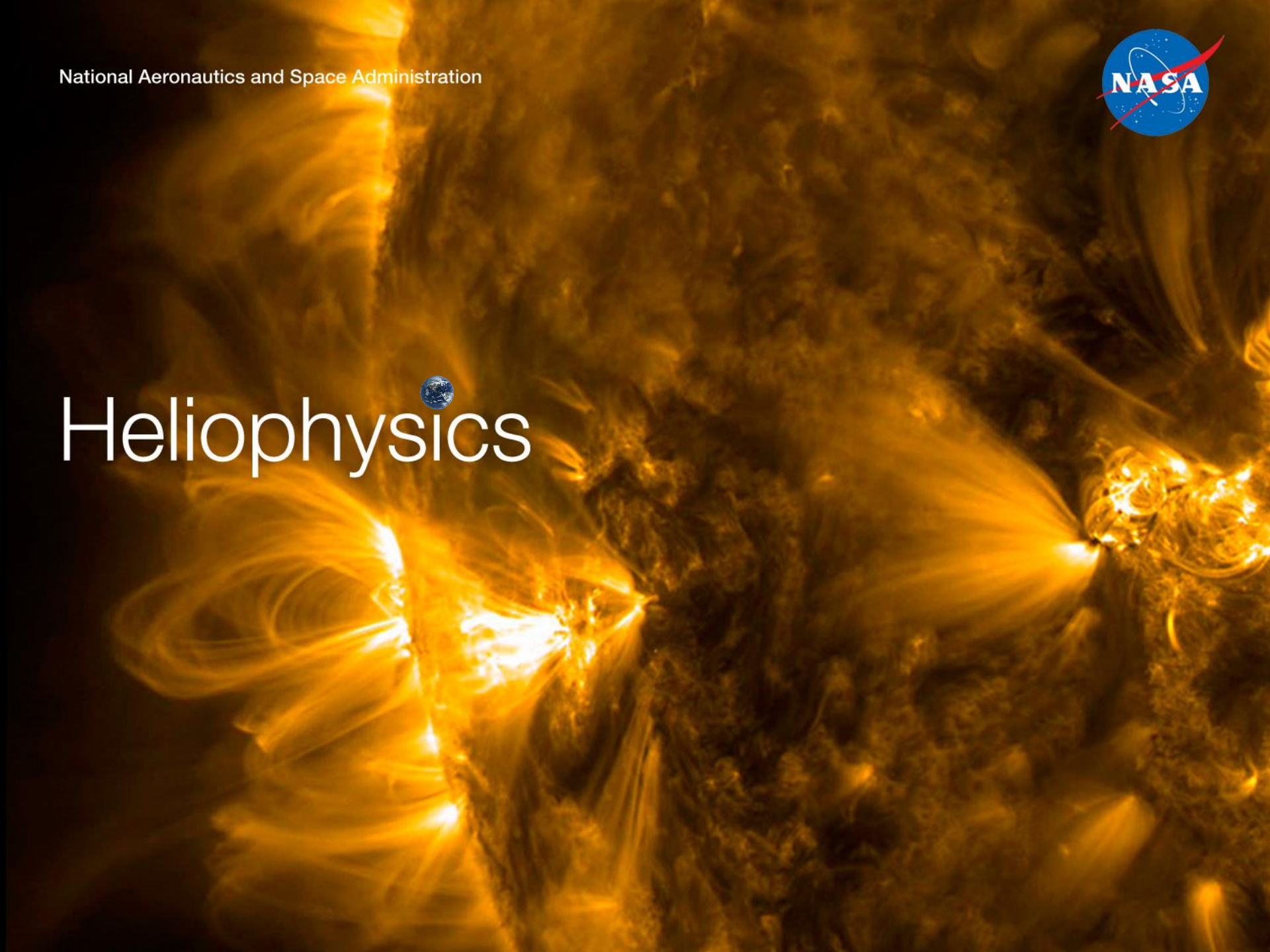
Doug Duncan, University of Colorado
Mark Robinson, Arizona State University
Harlan Spence, University of New Hampshire
James Green, University of Colorado at Boulder
Robert Kirshner, Harvard University
Susan Avery, Woods Hole Oceanographic Institute (NEW)

David Spergel, Chair of Space Studies Board (*ex officio* member)

Outline

- **Science Results**
- Programmatic Status
- Findings

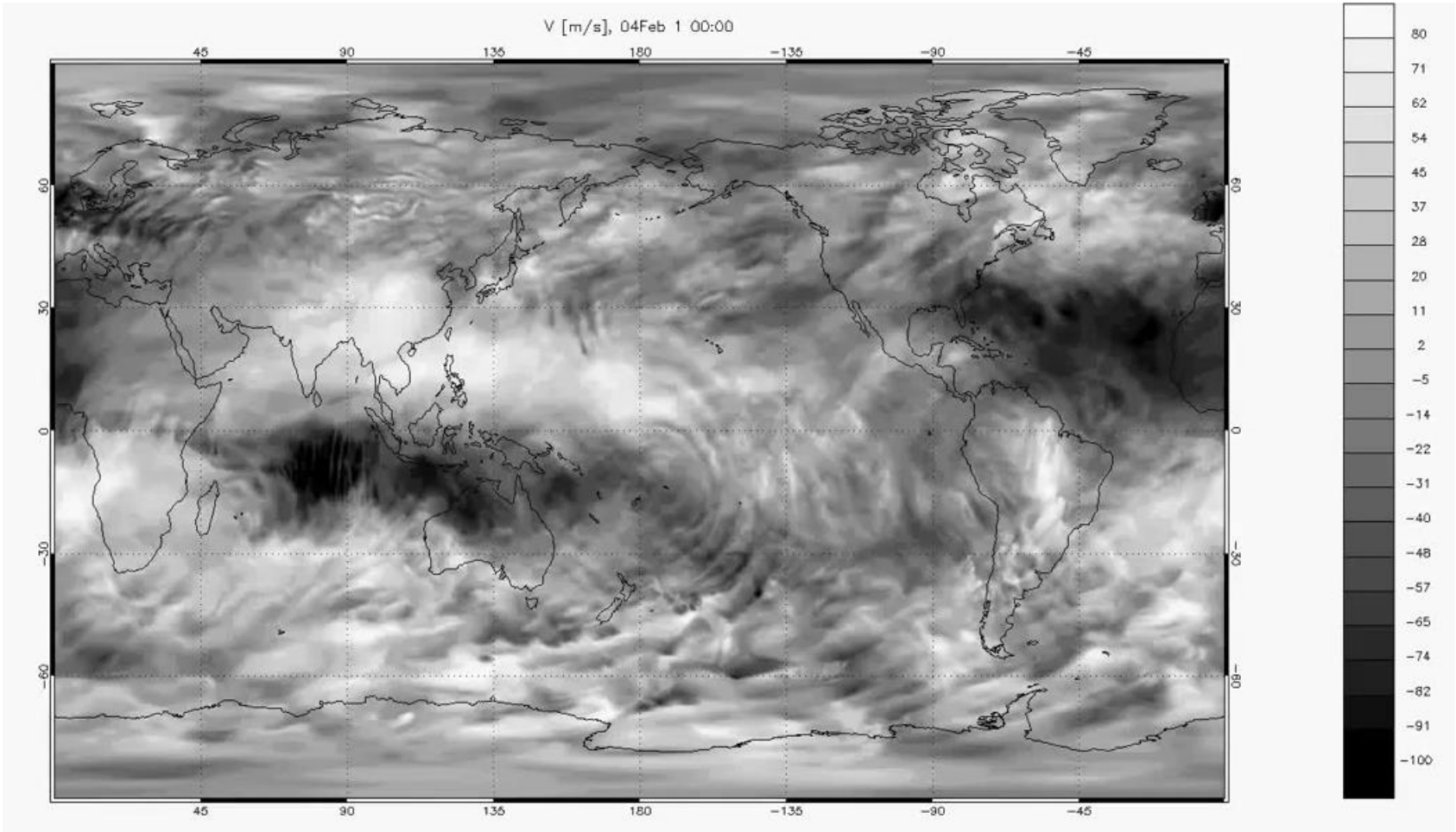
National Aeronautics and Space Administration



Heliophysics

Gravity Waves in the Mesopause Region

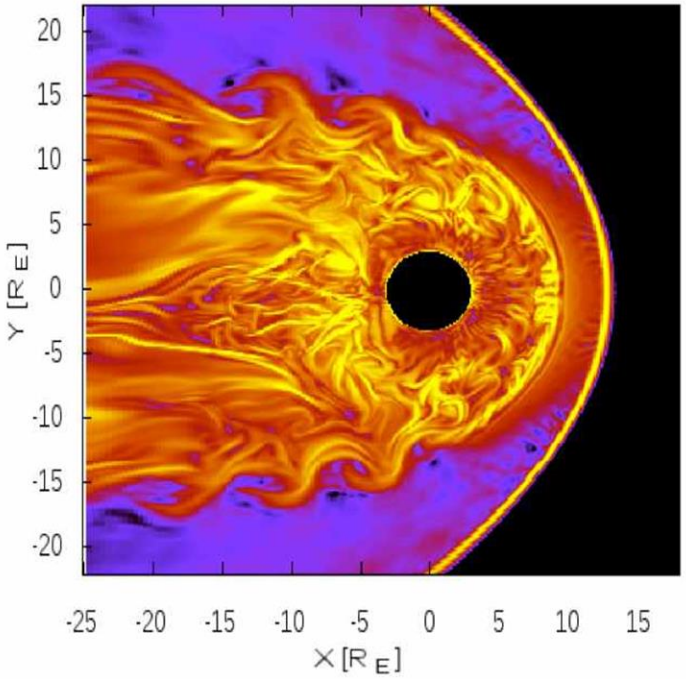
Whole **A**tmosphere **C**ommunity **C**limate **M**odel Meridional Winds at 95 km during February



- Unprecedented mesoscale-resolving whole atmosphere general circulation model
- WACCM at ~0.25° horizontal resolution and 0.1 scale height vertical resolution
- Reveals increasing dominance of explicitly resolved gravity waves at high altitudes
- Note planetary-scale extent of a concentric GW excited by a tropical cyclone

[*after Liu et al.,* 2014]

The wavy magnetopause

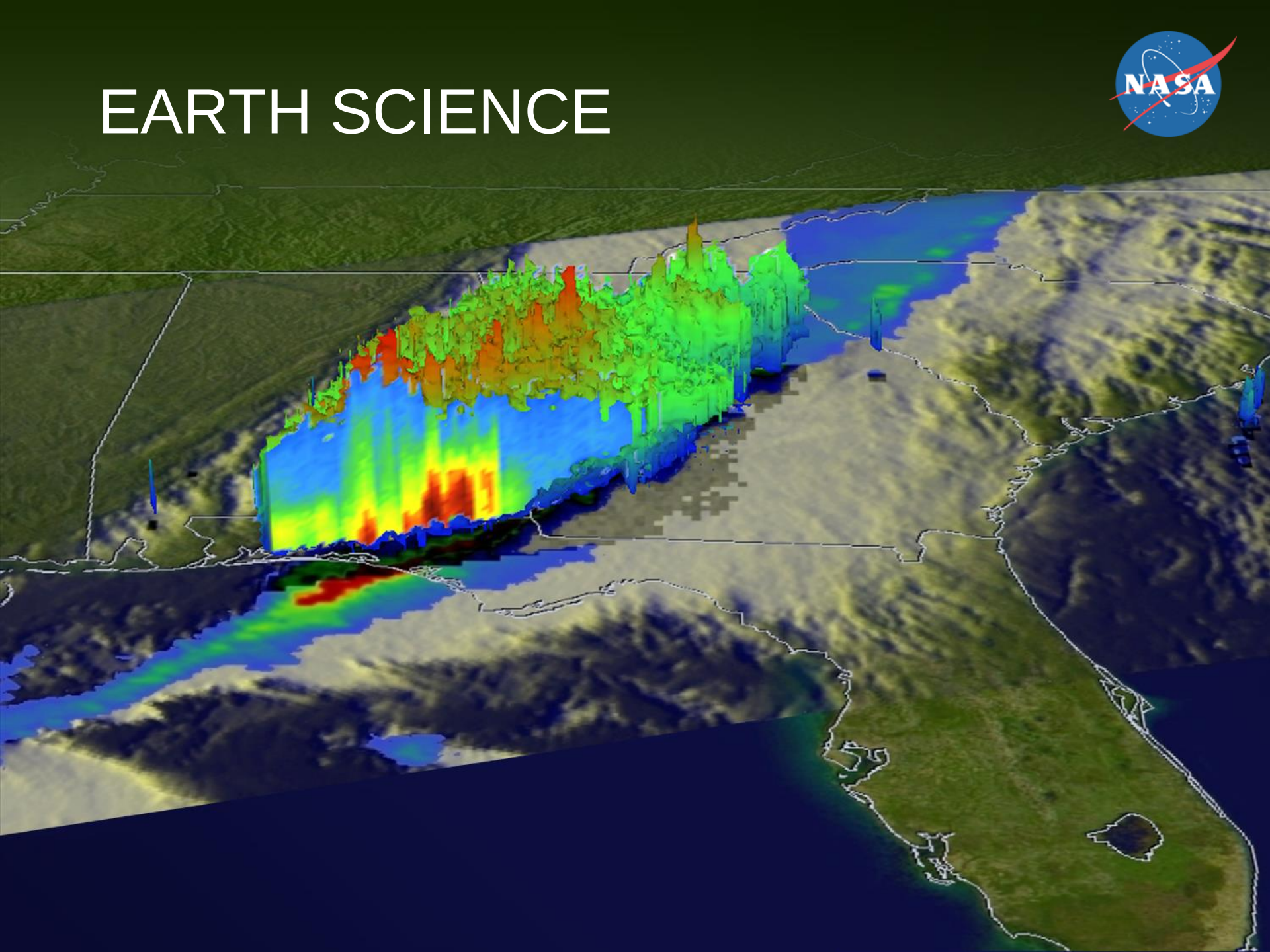


ABOVE: This magnetosphere simulation shows, in color code, the electrical current density in the equatorial plane. The wavy region, when Earth's magnetic field interacts with the streaming solar wind, is the magnetopause. BELOW: Example of similar waves in the atmosphere.

- Using >1000 hours of THEMIS magnetopause observations, Kavoshi & Raeder find that Kelvin-Helmholtz (KH) waves -- produced by solar wind flow shear at Earth's magnetopause -- are quite common (see simulation, top left).
- These waves are similar to wind-over-water waves or wind-shear waves in atmospheric clouds (see example bottom, left).
- These waves occur 19% of the time at the magnetopause, much more often than previously thought. KH waves are also found when they are least expected, during slow solar wind (~270 km/s).
- Such high KH occurrence frequency has implications for plasma entry into the magnetosphere, and for excitation of ultra-low low frequency waves inside Earth's magnetosphere which can, in turn, energize the radiation belts.

Kavosi & Raeder, *Nature Communications*, 2015.
http://www.unh.edu/news/releases/2015/05/ds11breakingwaves.cfm

EARTH SCIENCE



DSCOVR EPIC First-Light Release – 20 July

Tweets Tweets & replies Photos & videos

President Obama @POTUS · 2m

Just got this new blue marble photo from @NASA. A beautiful reminder that we need to protect the only planet we have.

872 1.3K View photo

DSCOVR EPIC First-Light Release – 20 July

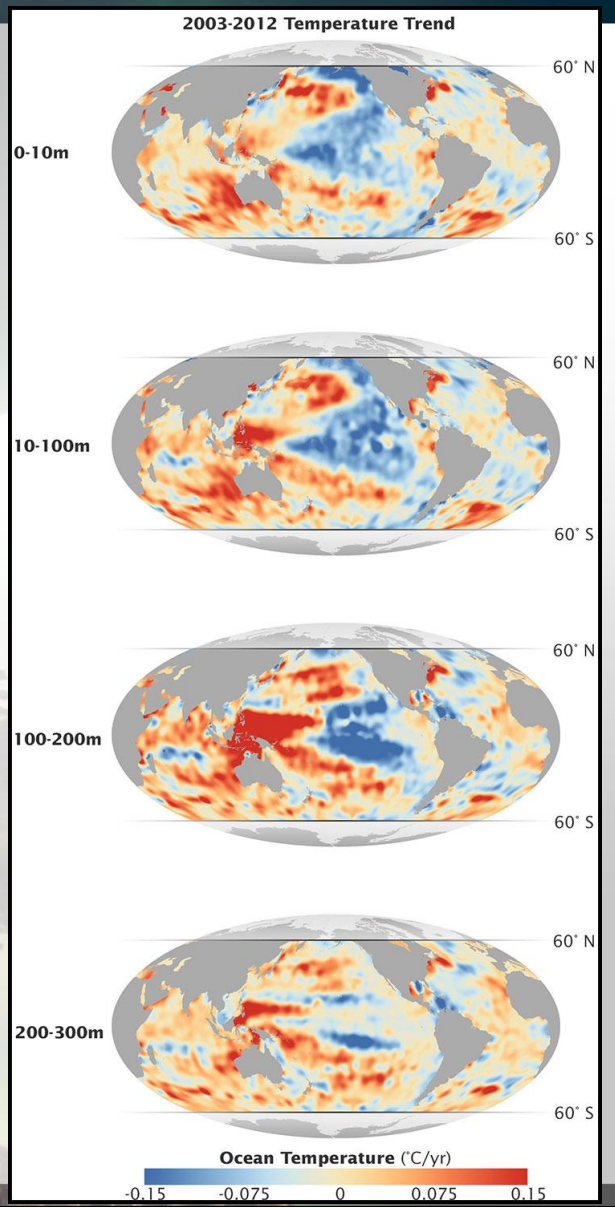
Recent hiatus caused by decadal shift in Indo-Pacific heating

Veronica Nieves, Josh K. Willis, and William C. Patzert | Science | JULY 2015 | doi: 10.1126/science.aaa4521

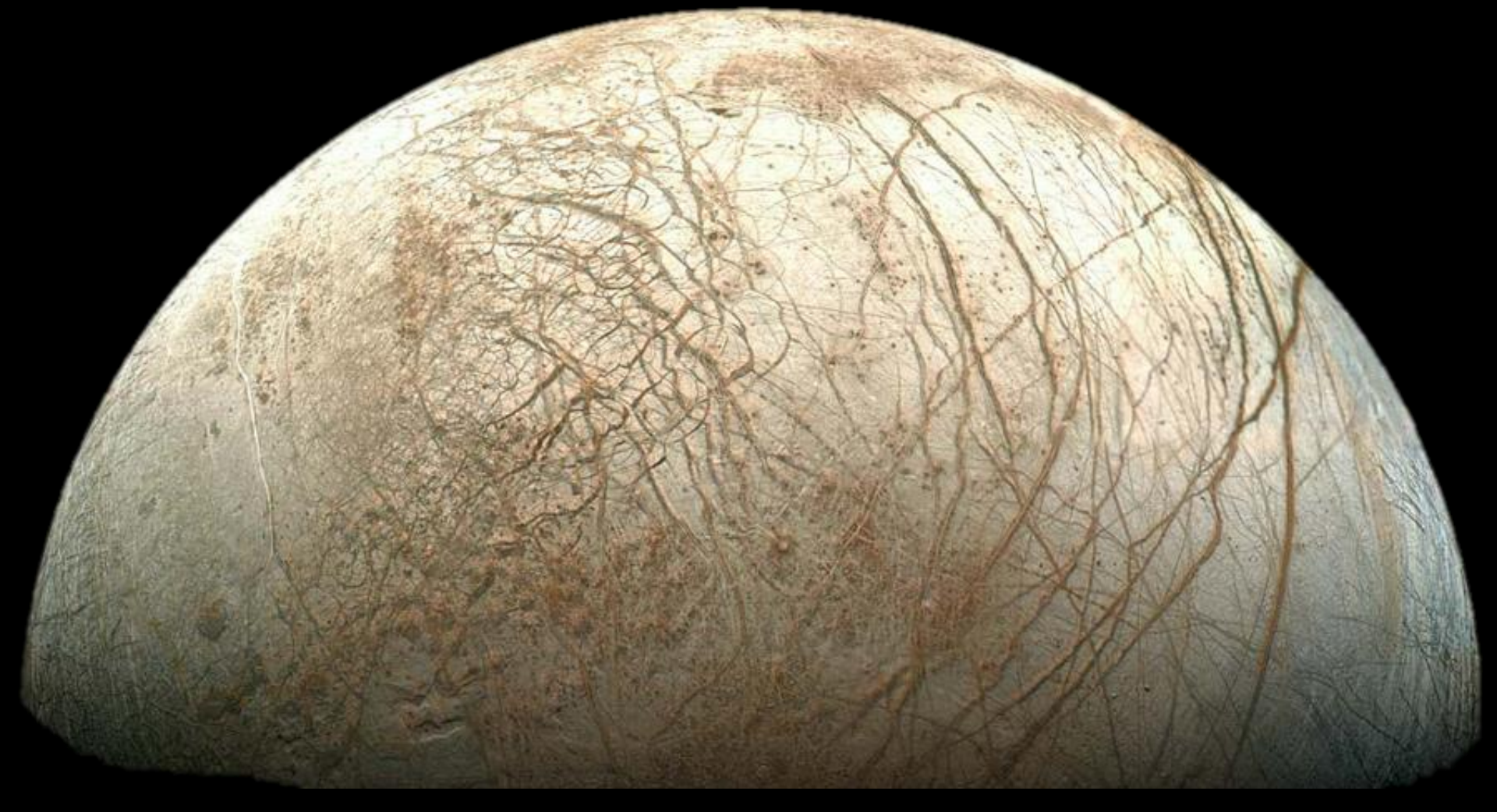
A new NASA study finds that cooling in the top 100 m layer of the Pacific Ocean was mainly compensated by warming in the 100 to 300 m layer of the Indian and Pacific Oceans in the last decade since 2003. Recent modeling studies have proposed different scenarios to explain the slowdown in surface temperature in the most recent decade. This study's examination of observational data over the last two decades shows some significant differences compared to model results from reanalyses, and provides the most definitive explanation of how the heat was redistributed. These findings support the idea that the Indo-Pacific interaction in the upper-level water (0-300 m depth) regulated global surface temperature over the past two decades and can fully account for the recently observed hiatus. Furthermore, as previously shown for interannual fluctuations, the decade long hiatus that began in 2003 is the result of a redistribution of heat within the ocean, rather than a change in the net warming rate.

Left: An Argo float, foreground. The new study included direct measurements of ocean temperatures from the global array of 3,500 Argo floats and other sensors.

Right: Temperature trend data from the global ocean (2003-2012) at four depths shows the most rapidly warming water at depths of about 330-660 feet (100-200m) in the western Pacific and Indian Oceans.

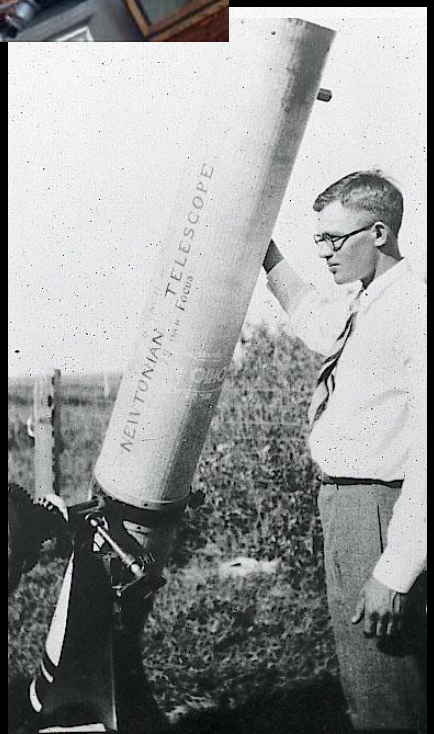


Planetary Science



Discovery of Pluto (1930)

Percival Lowell
(1855-1916)



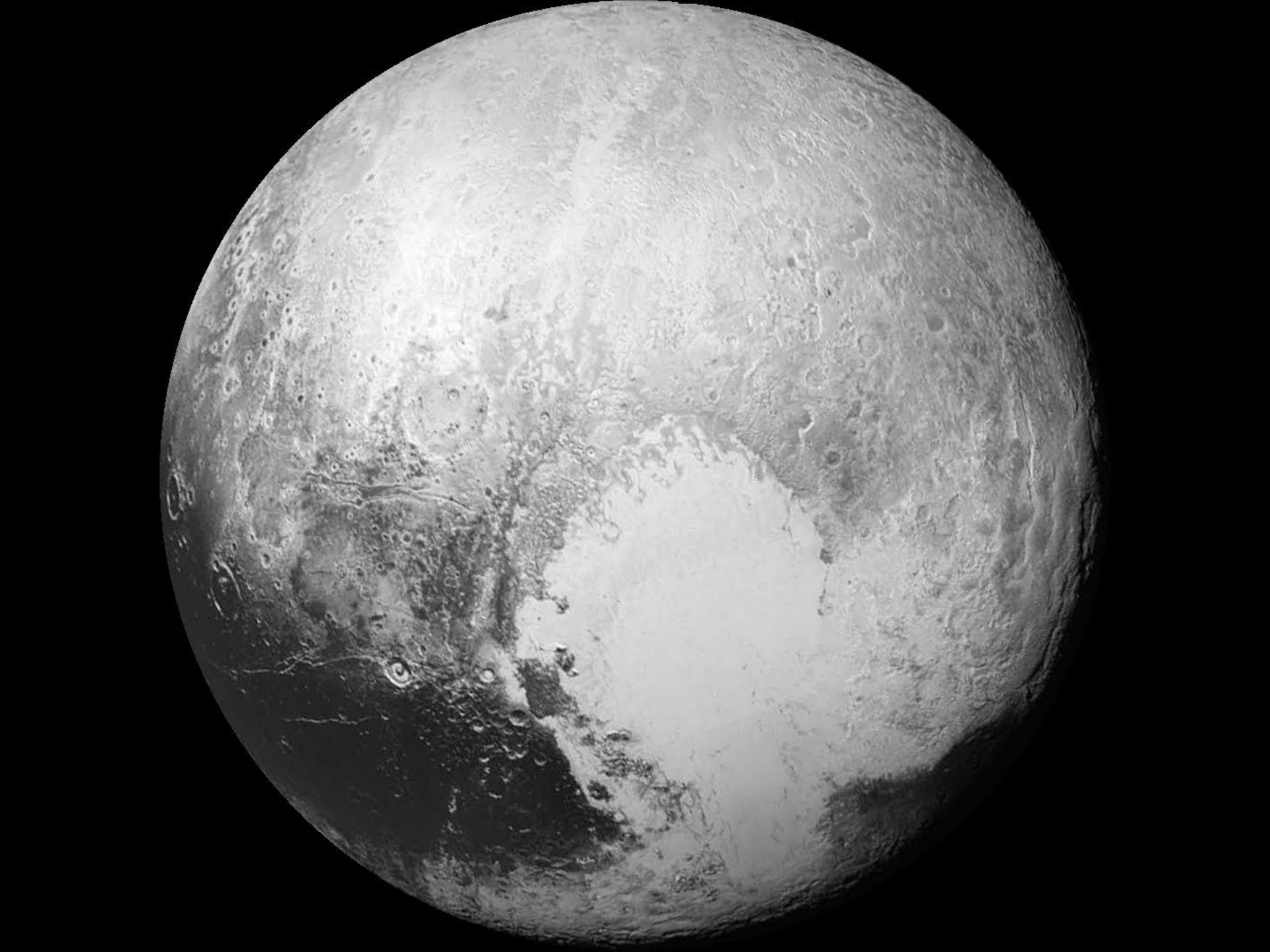
Clyde Tombaugh
(1906-1997)

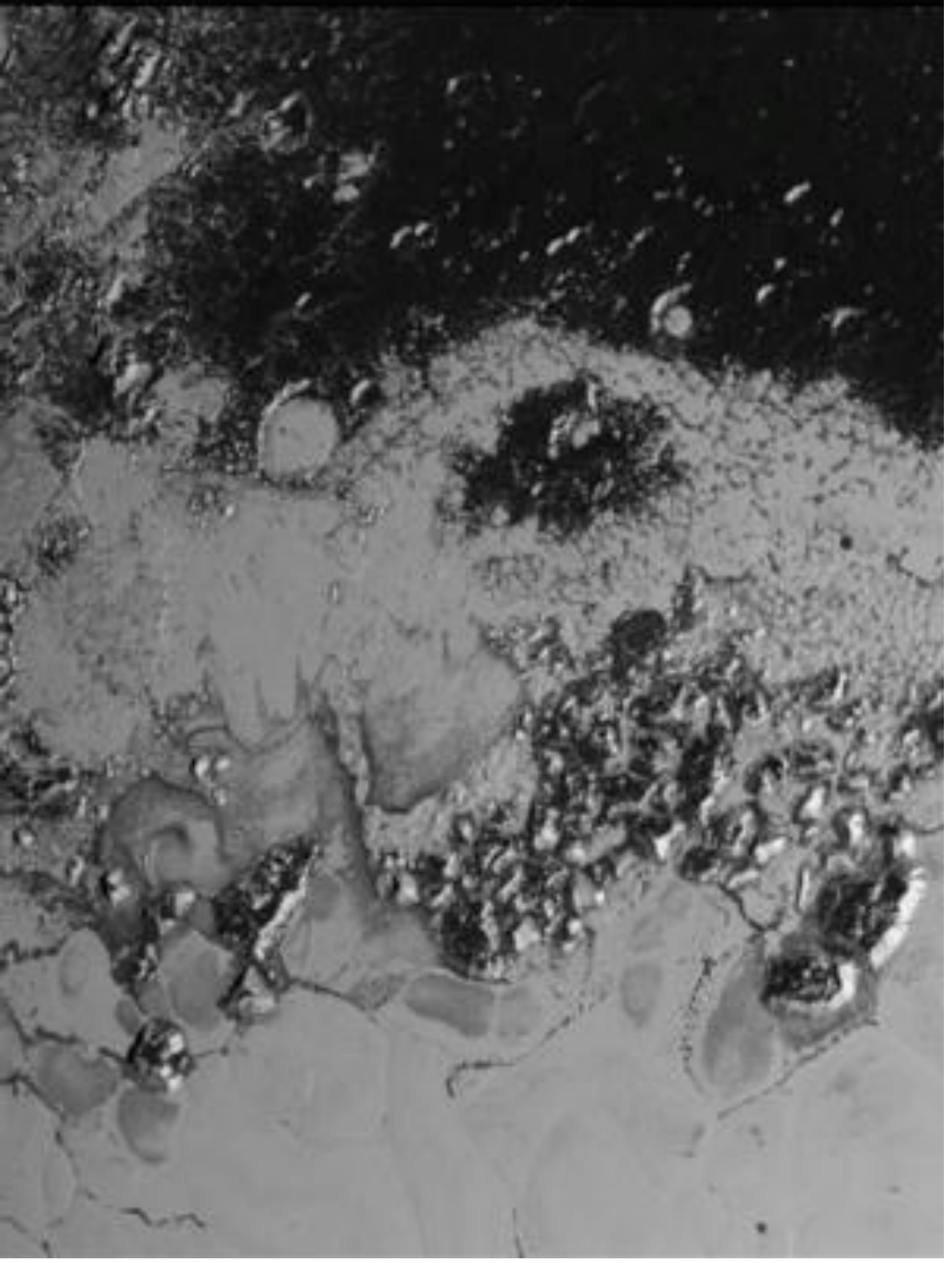
DISCOVERY OF THE PLANET PLUTO

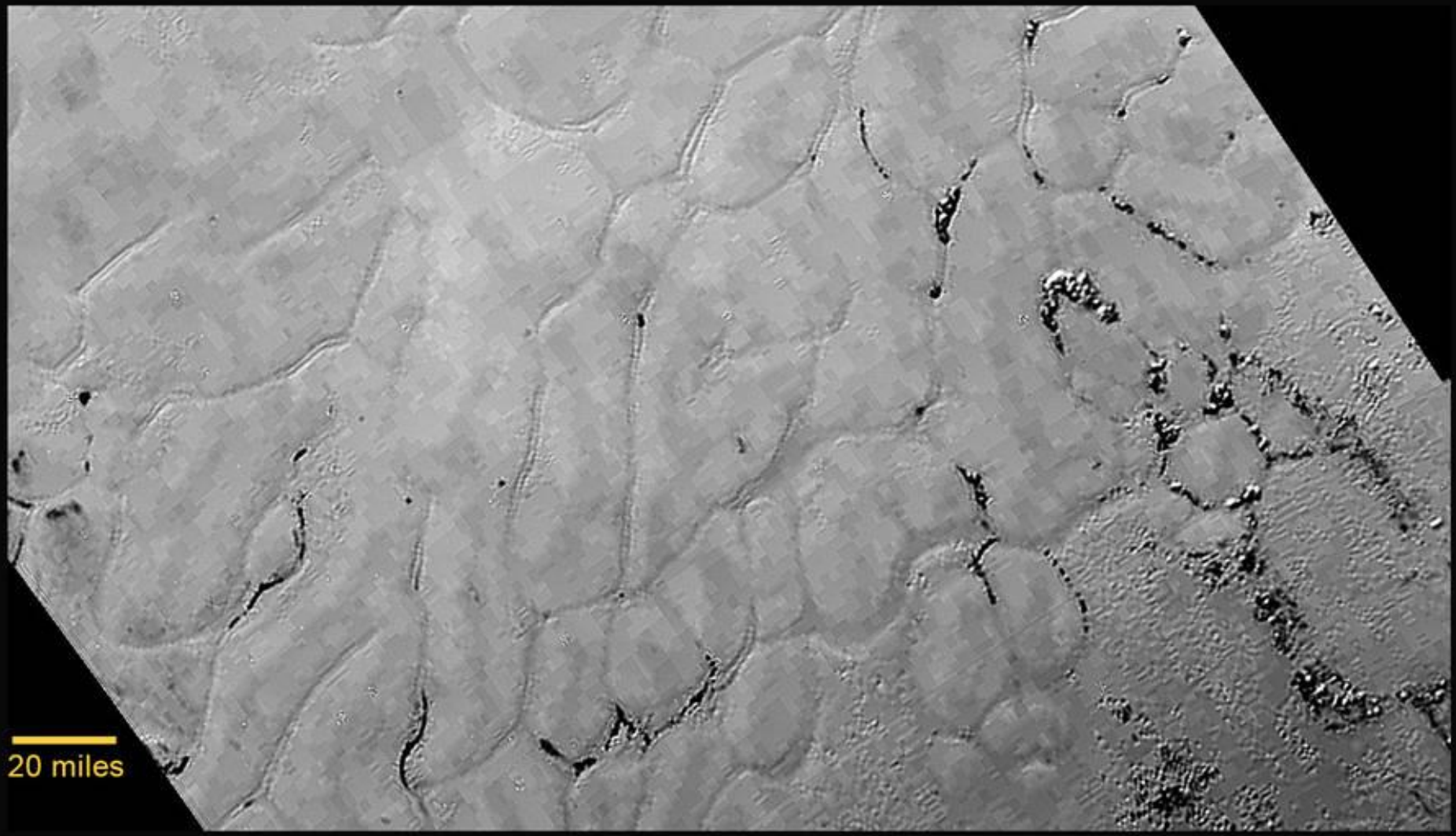
January 23, 1930

January 29, 1930

The clearest map of Pluto prior to New Horizons (Buie et al., 2010)

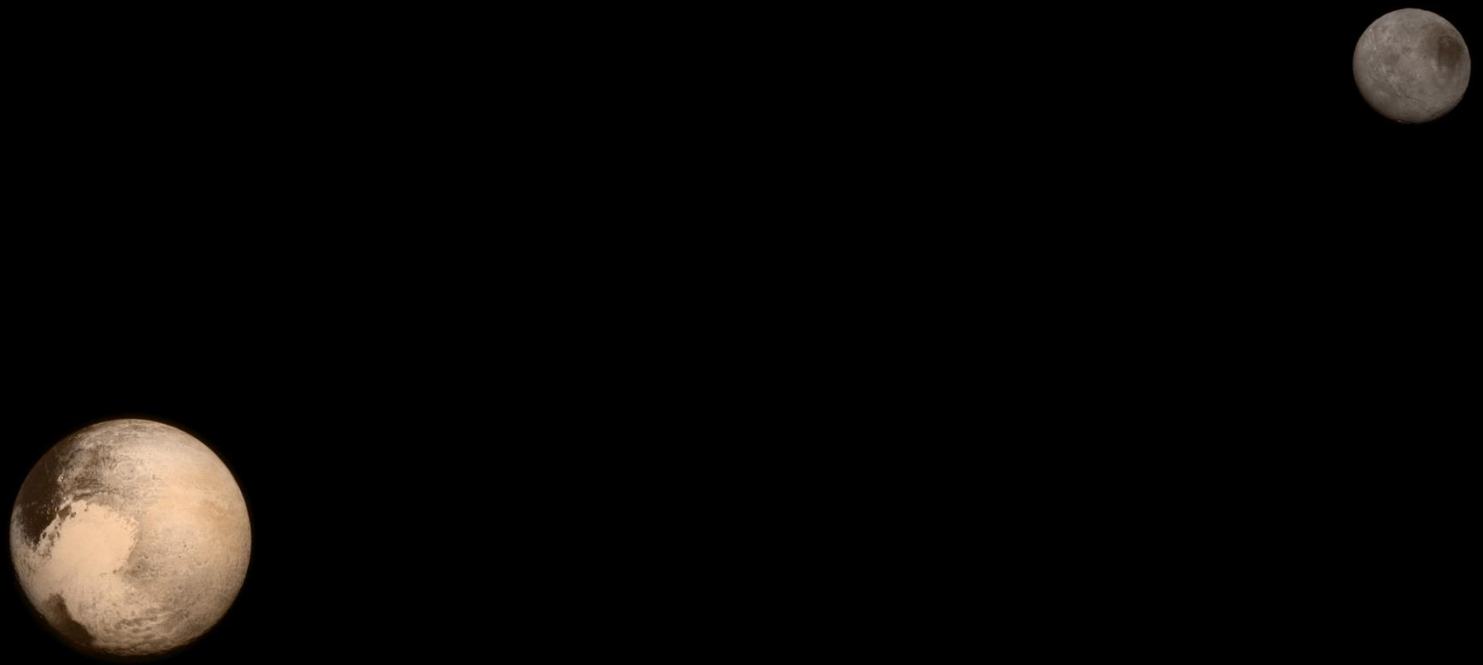


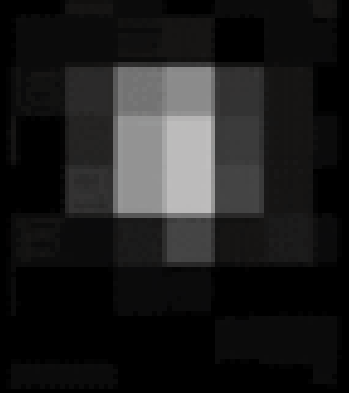



20 miles

Pluto July 14, 2015

Colors of Pluto and Charon

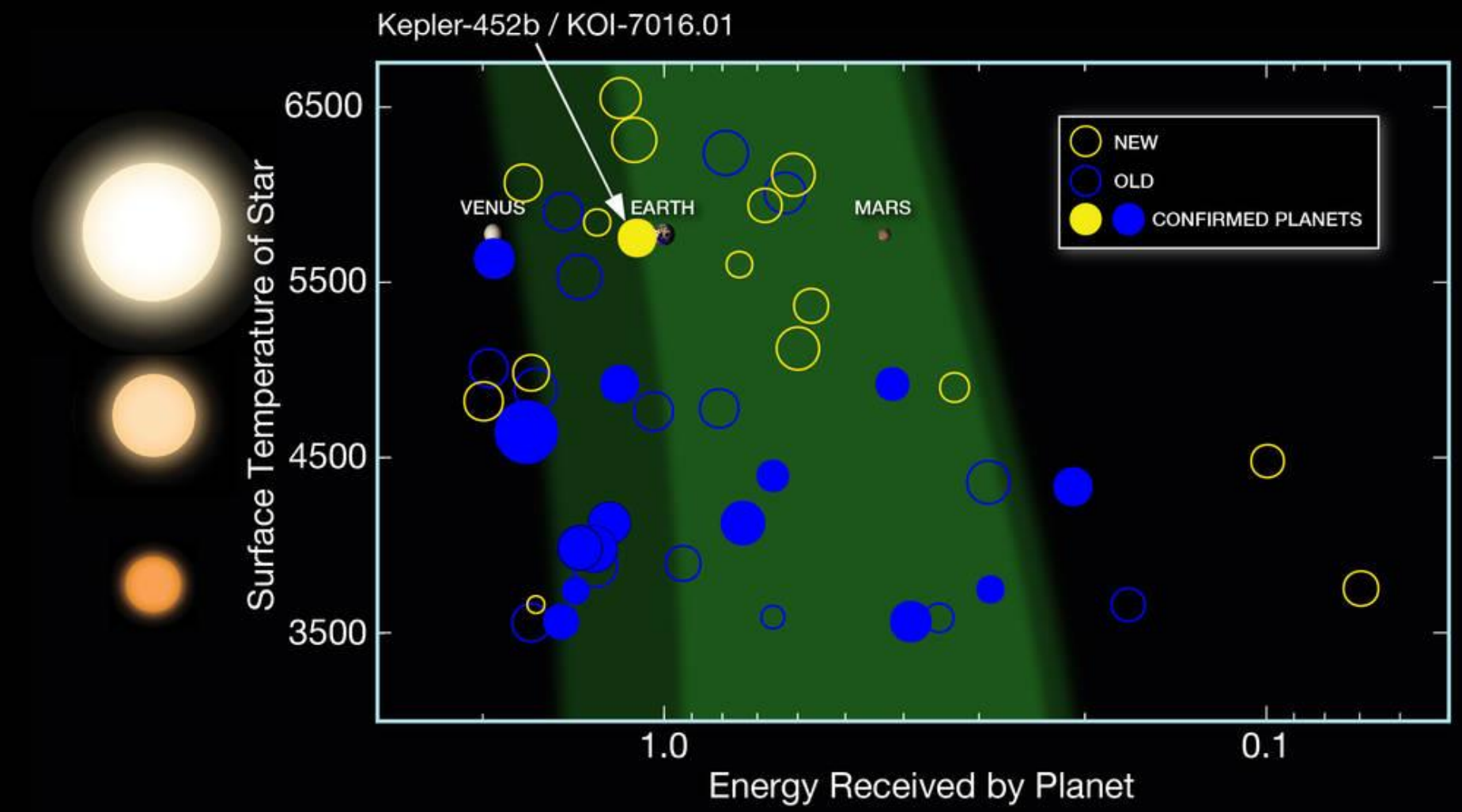




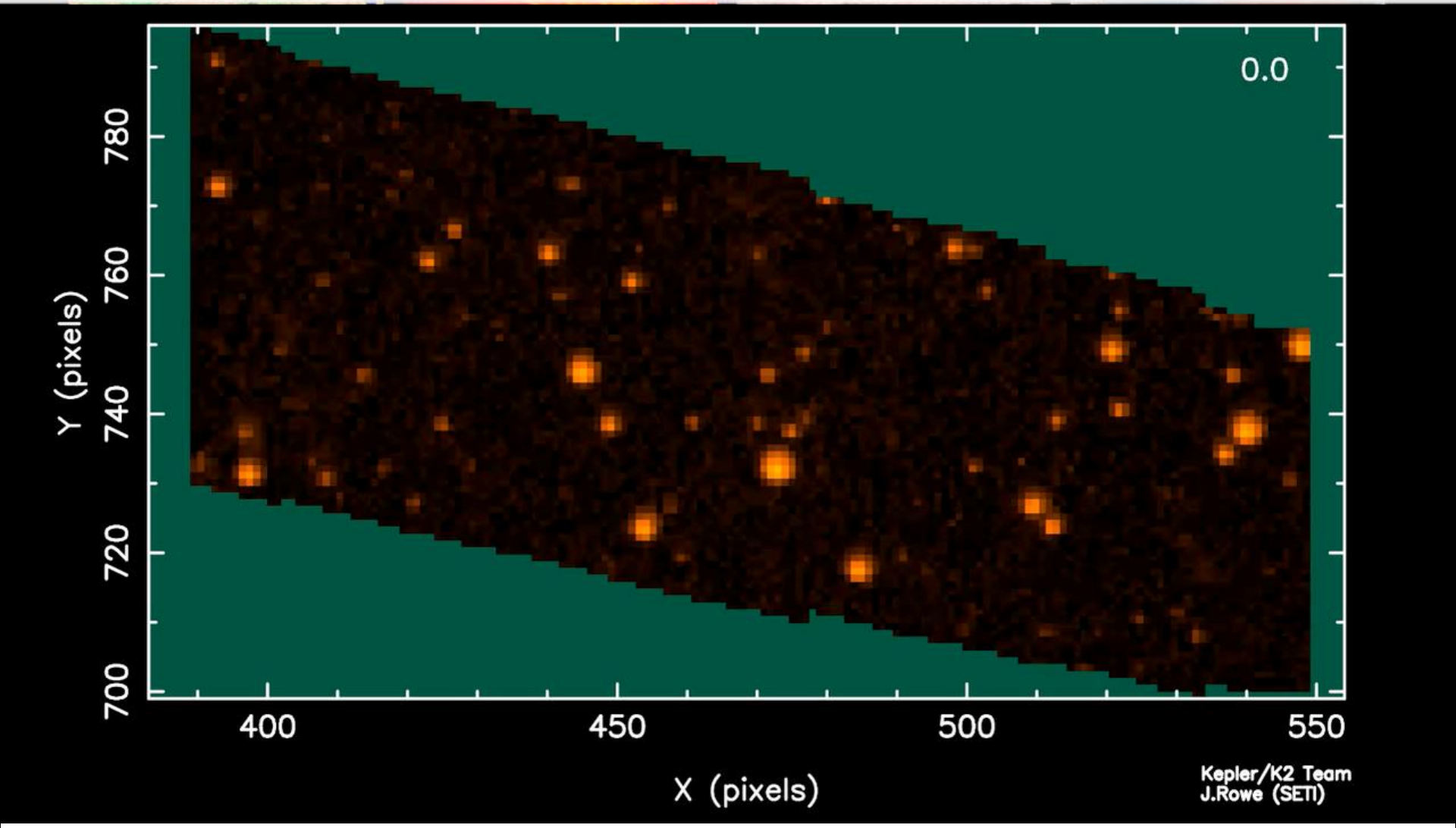
National Aeronautics and Space Administration

Astrophysics

Twelve New Small Kepler Candidates in the Habitable Zone

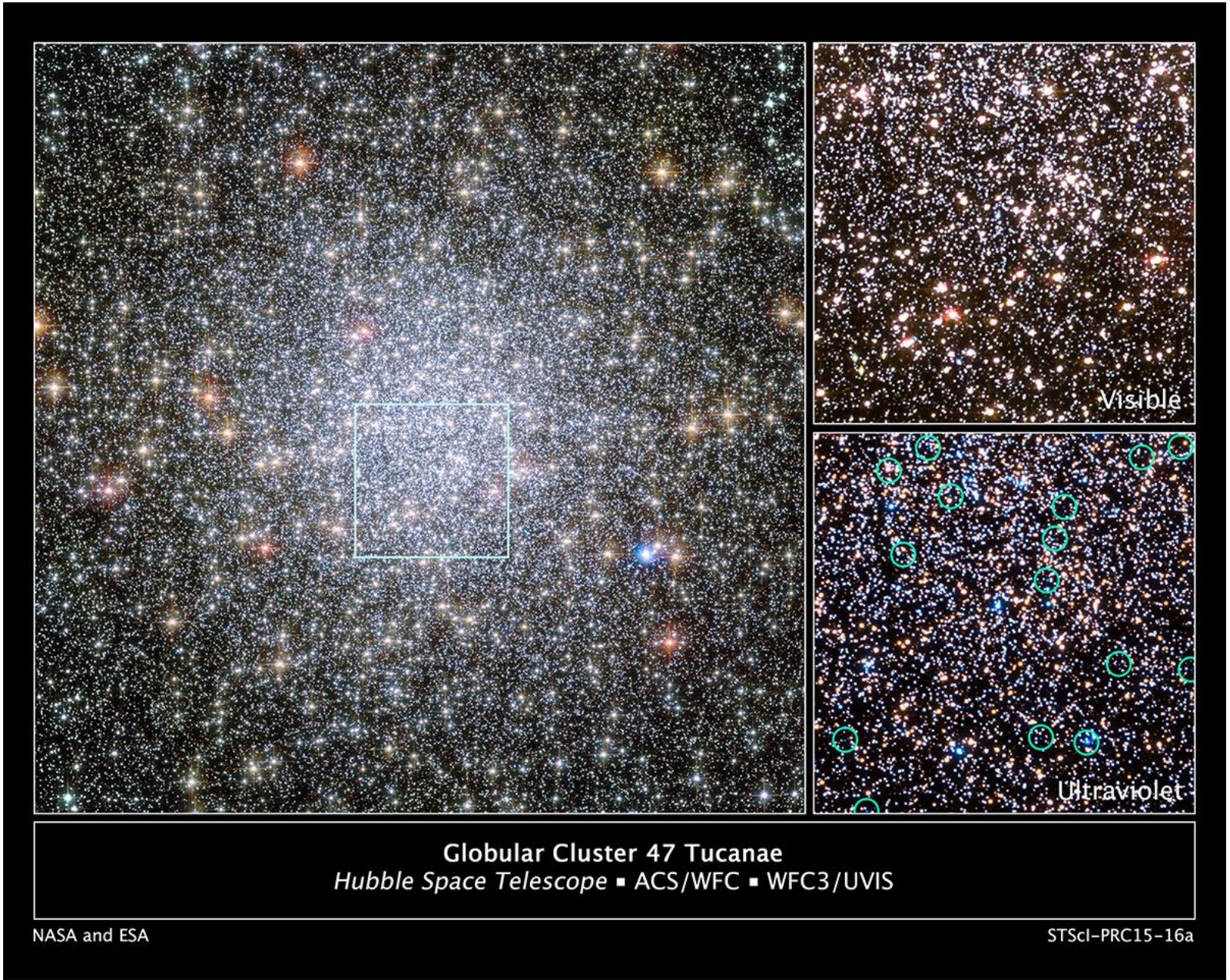


Kepler/K2 Campaign 3 Observes Neptune



Movie available at: http://www.nasa.gov/feature/kepler/ames/kepler-observes-neptune-dance-with-its-moons

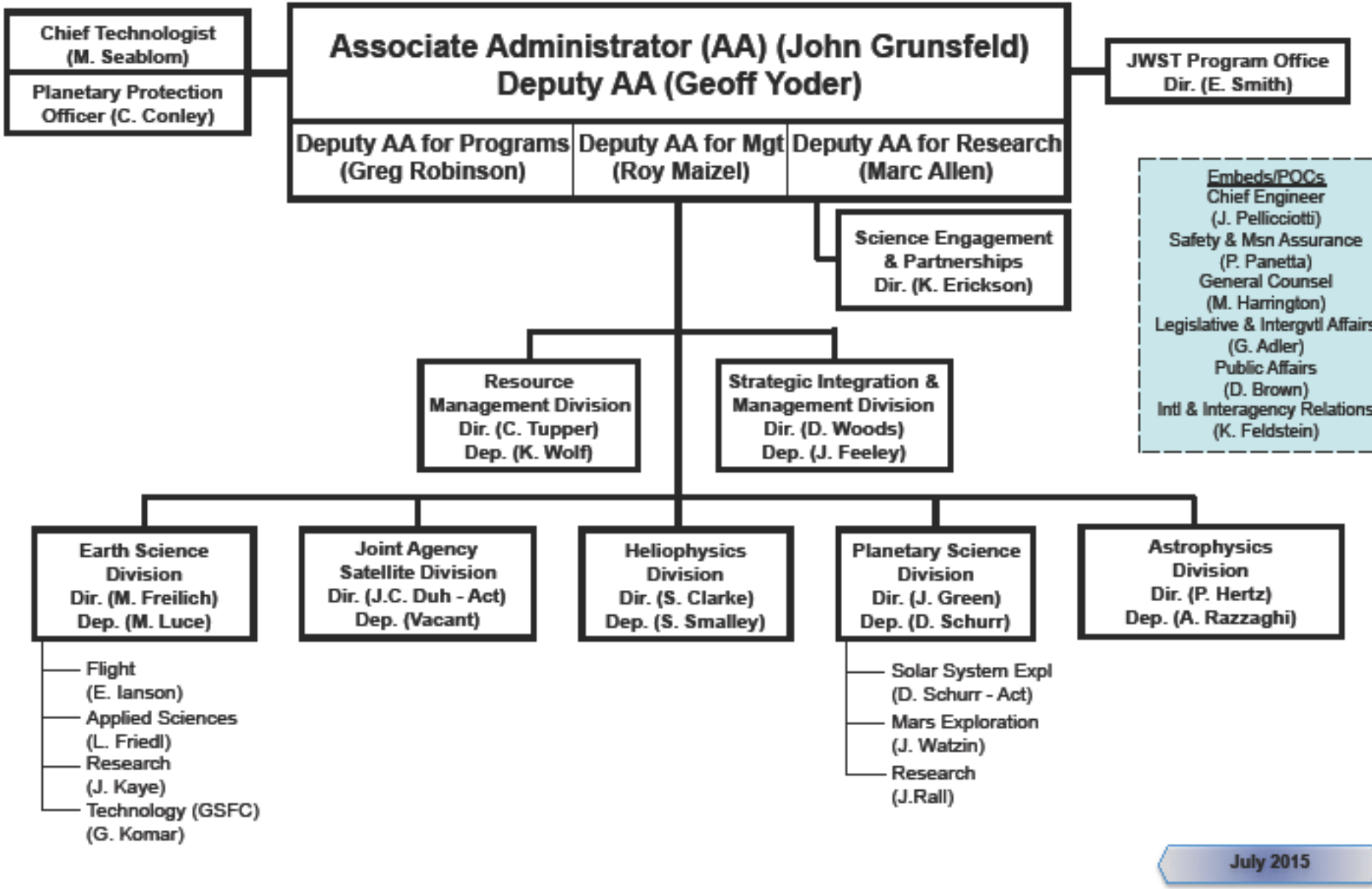
Hubble Captures Stellar Exodus in Action



Outline

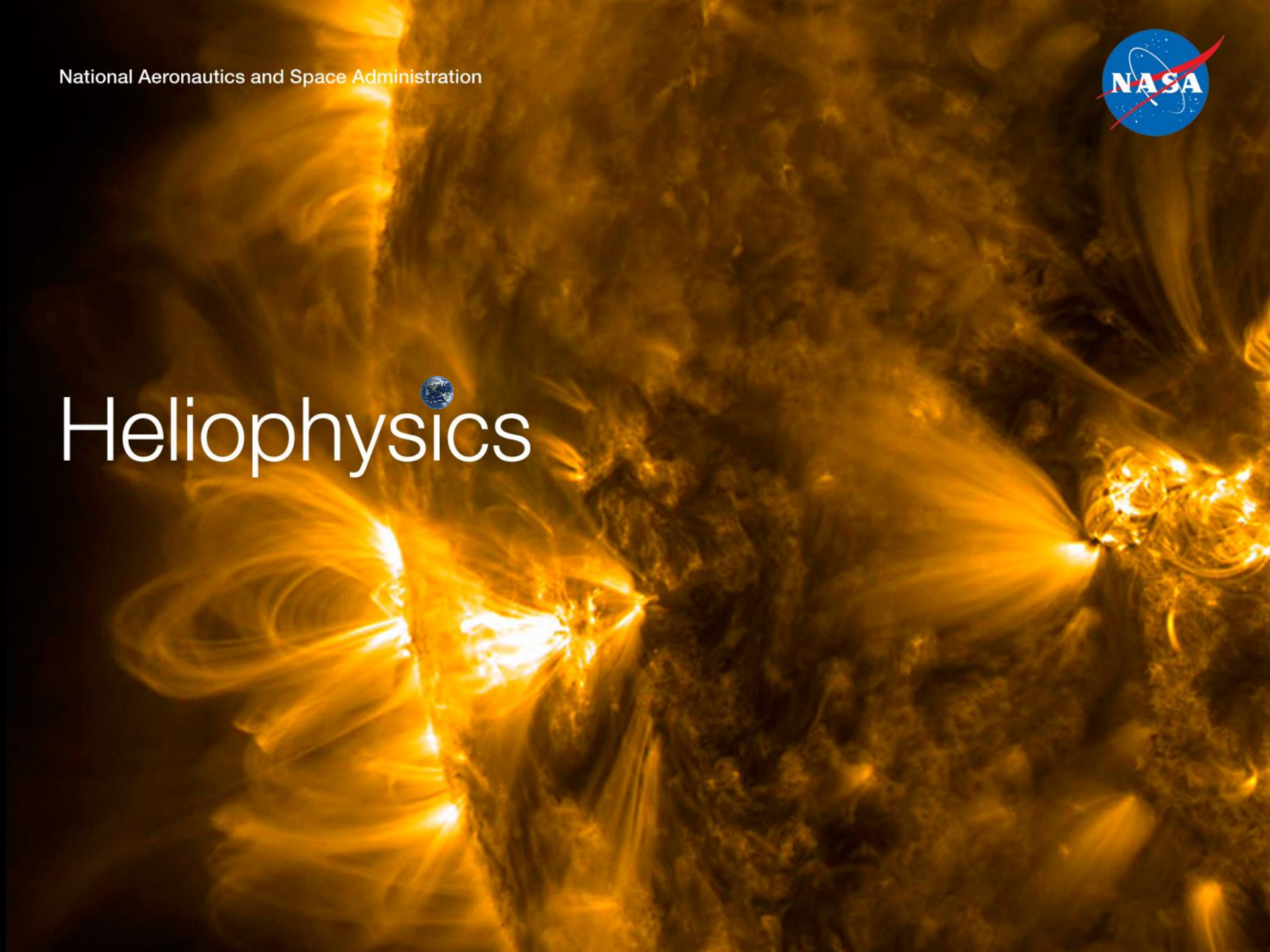
- Science Results
- **Programmatic Status**
  - Heliophysics
  - Earth Science
  - Planetary Science
  - Astrophysics
  - Other Reports
- Findings & Recommendations

SMD Organization



July 2015

National Aeronautics and Space Administration



Heliophysics

HPS July 2015 Senior Review Comment

All fifteen HPD extended missions in the Heliophysics System Observatory are being extended, including the returning missions ACE, AIM, CINDI, Hinode, IBEX, RHESSI, STEREO, TIMED, THEMIS, TWINS, Voyager, and Wind, and the IRIS, SDO, and Van Allen Probe missions that are entering their extended phases of operation. These missions, taken together, form a flexible and dynamic distributed system that provides forefront science and also operationally capable space weather data.

The HPS was very pleased with the decision to continue all of the reviewed HPD missions.

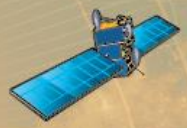
Heliophysics Program 2015-2024

Solar Terrestrial Probes

Magnetospheric Multiscale (MMS)
March 2015

STP #5
2023

Living With a Star



Space Environment Testbeds (SET)
October 2016

Solar Probe Plus
July 2018

Solar Orbiter Collaboration (with ESA)
October 2018

Explorers

Ionospheric Connection Explorer (ICON)
October 2017

Global-scale Observations of the Limb and Disk (GOLD)
April 2018

Heliophysics MO
2020

Heliophysics SMEX
2022

Heliophysics MO
2022

Heliophysics MIDEX
2024

Heliophysics MO
2024

Research Program

ROCKSAT-X - August 2015
Solar/Heliospheric - August 2015
Solar/Heliospheric - September 2015
UV/Optical Astrophysics - October 2015

UV/Optical Astrophysics - October 2015
Solar/Heliospheric - October 2015
UV/Optical Astrophysics - November 2015
Geospace - November 2015

Geospace - November 2015
High Energy Astrophysics - December 2015

Ongoing

Heliophysics Missions
Astrophysics Missions
Planetary Missions

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

Where is the Heliophysics Division Going?

Primary Focus

- ***Ensure a more balanced Heliophysics portfolio and enable a continuing robust and long-term Heliophysics System Observatory and research programs.***

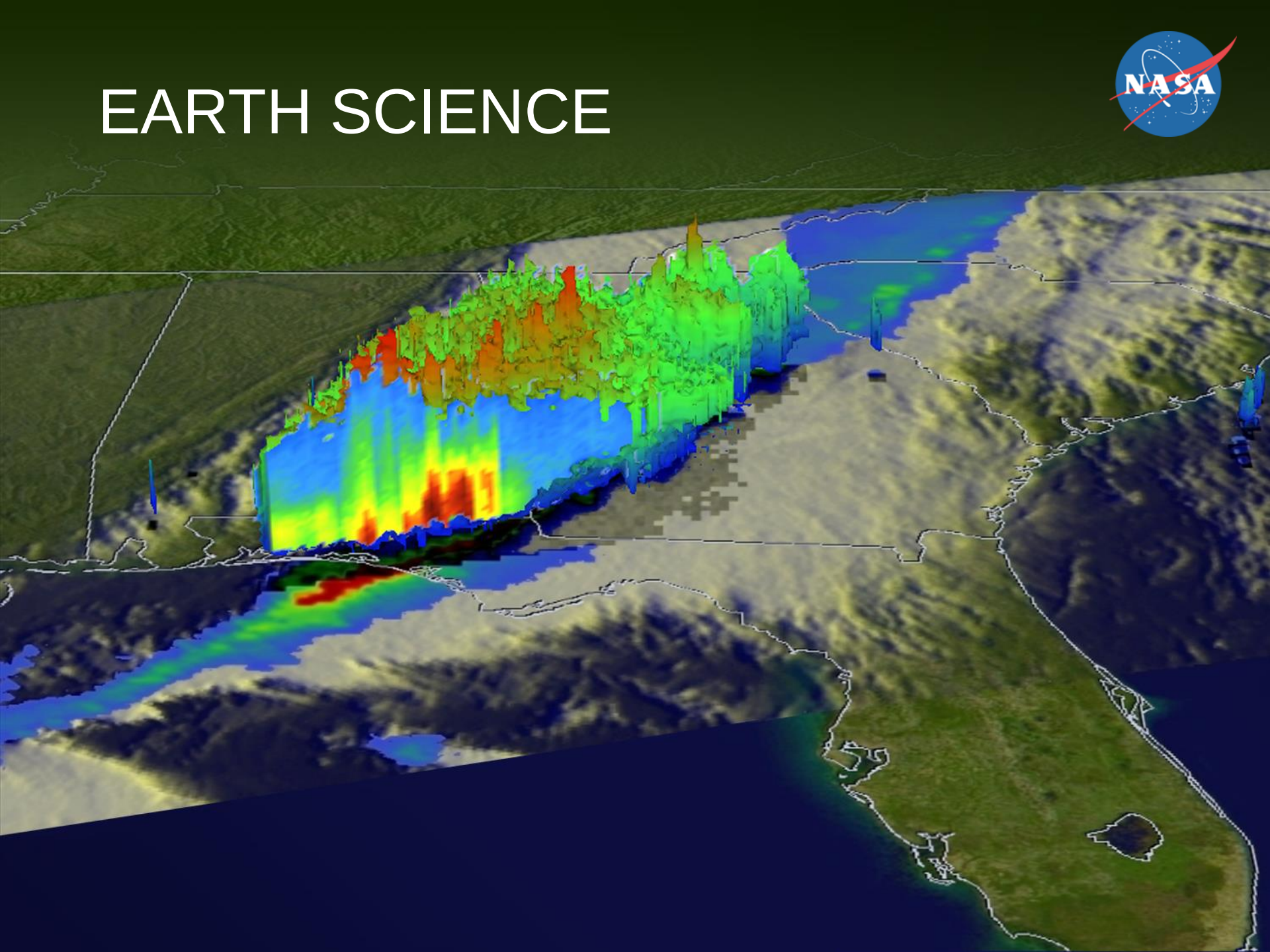
✓ **Assessing Division Resource Needs**

✓ **Re-Balancing Staff Work-Load**

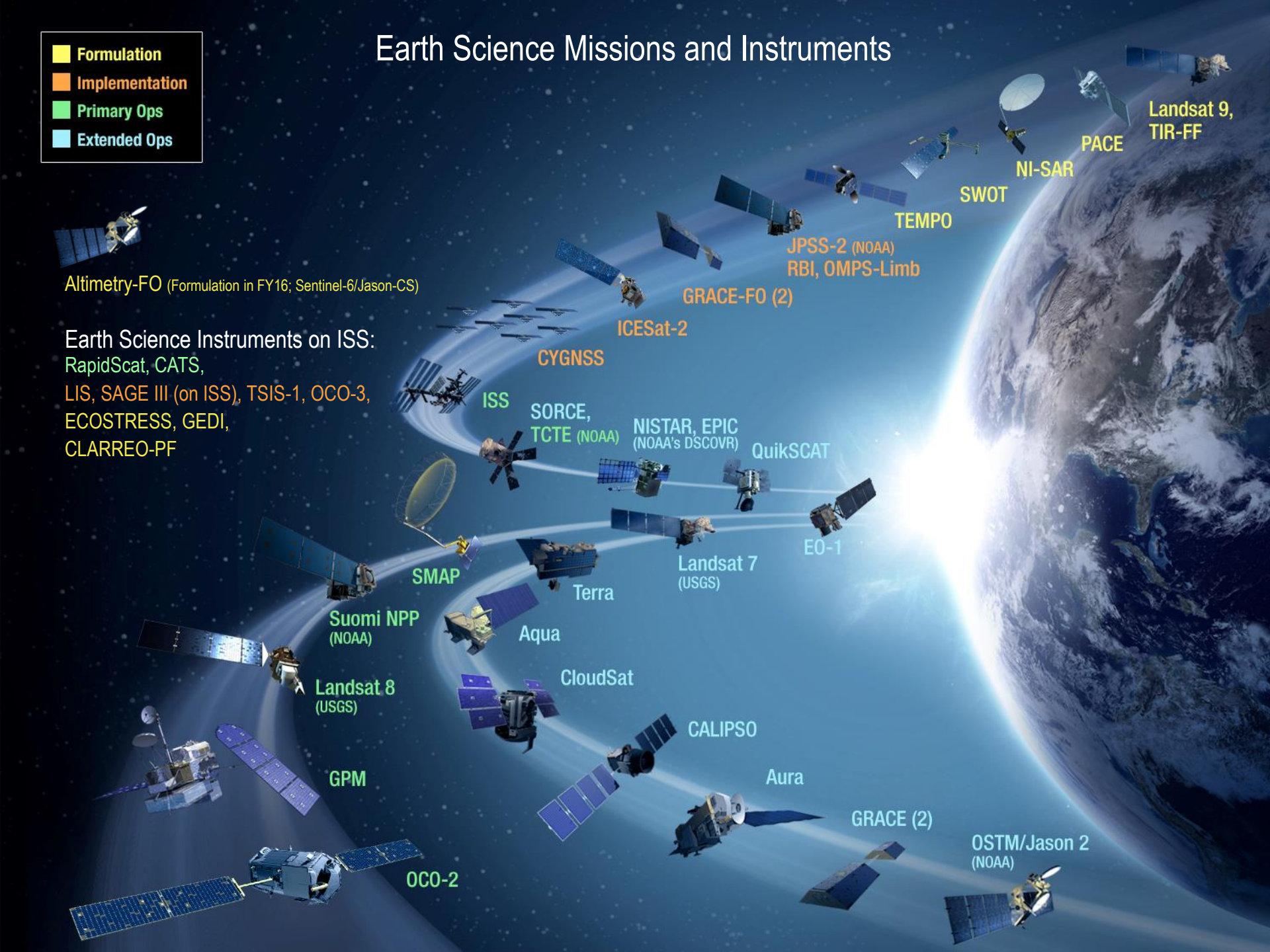
✓ **Participating in OSTP-led Space Weather Operations, Research and Mitigation (SWORM) Task Force activities**

- **Develop and Implement Long-Term Strategy for a Balanced Portfolio**
  - **Plan for more frequent, lower-cost missions by expanding Explorers and Missions of Opportunity**
  - **Commence development of the highest priority Strategic Program (STP, LWS) science targets, consistent with the budget and with Research and Explorer priorities**
  - **Work towards enhancing research programs (DRIVE) as recommended by the Decadal Survey**

EARTH SCIENCE

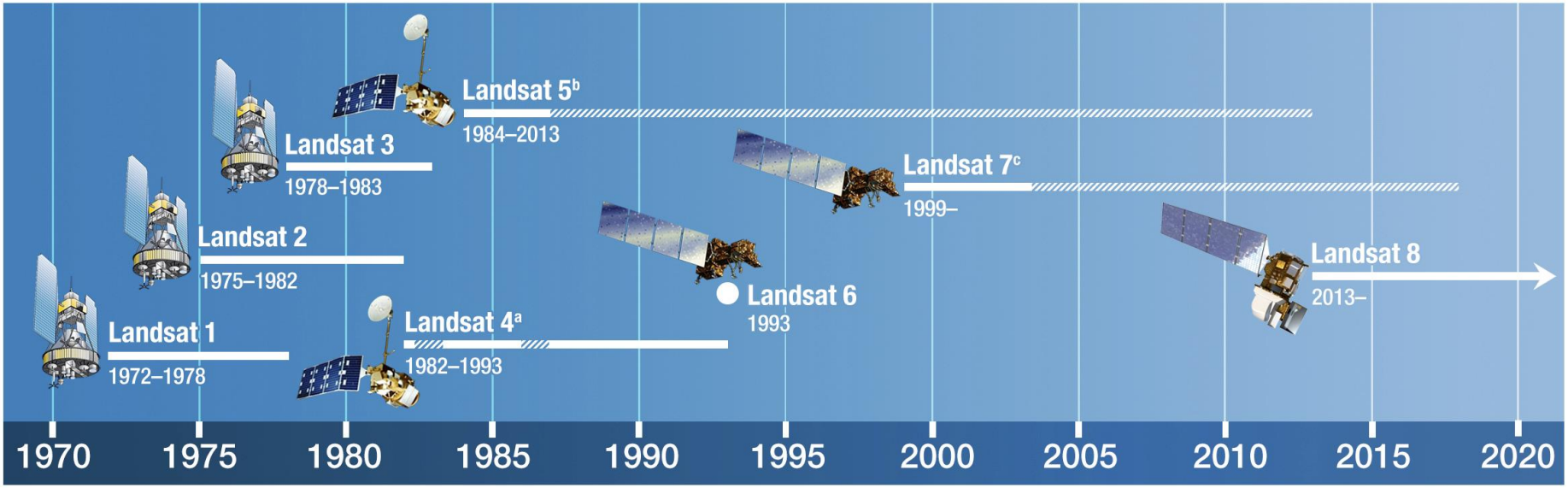


Earth Science Missions and Instruments



Sustainable Land Imaging 2016 - 2035

FY14, FY15 President's NASA budgets called for design and initiation of an affordable, ***sustained,*** Land Imaging Satellite System (with USGS) to extend the Landsat data record for decades – not just the "next mission"

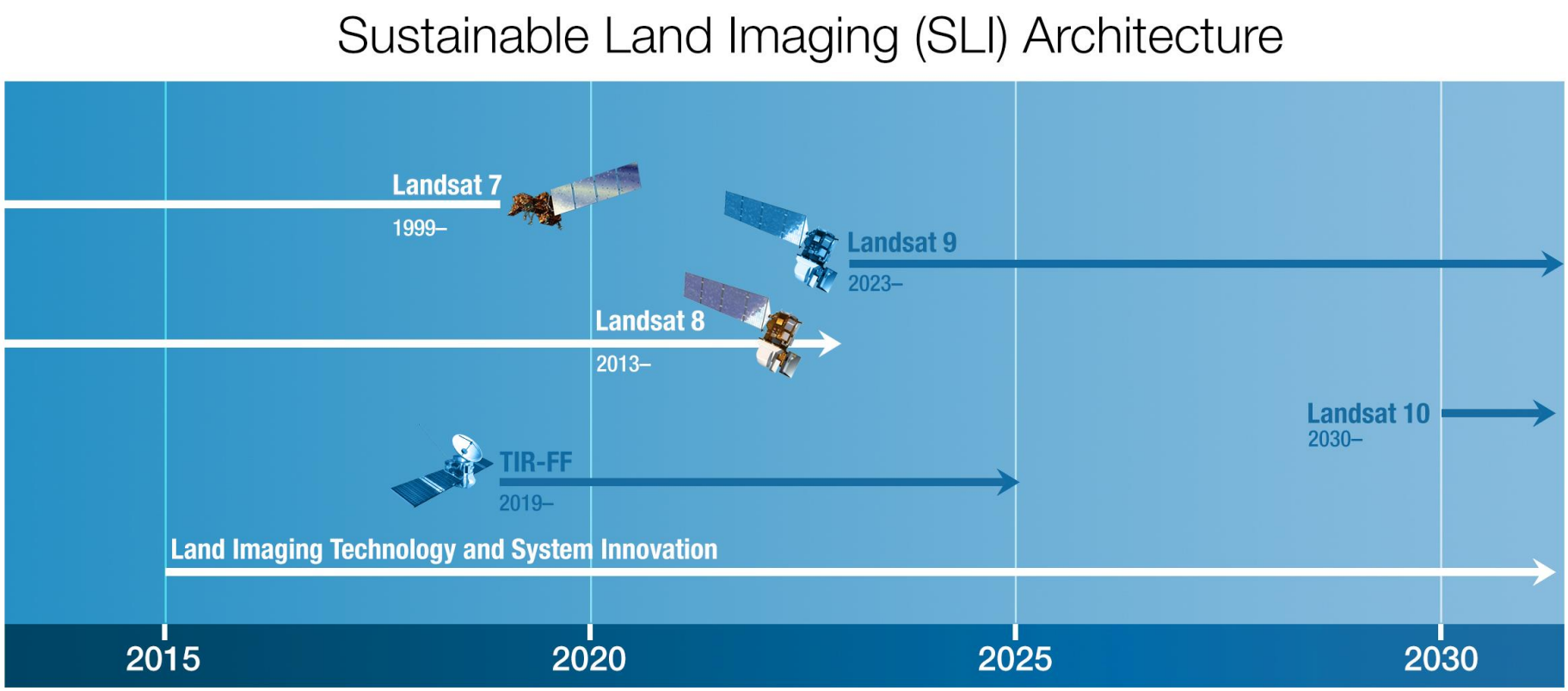


[a]Limited data due to transmitter failure soon after launch. Only 45,172 Landsat 4 Thematic Mapper scenes from 1982–1993 available for science users—~10 scenes/day (vs 725 scenes/day from L8)

[b]Data coverage limited to Continental US (CONUS) and International Ground Station sites after a transmitter failure in 1987; Multispectral Scanner turned off in August 1995

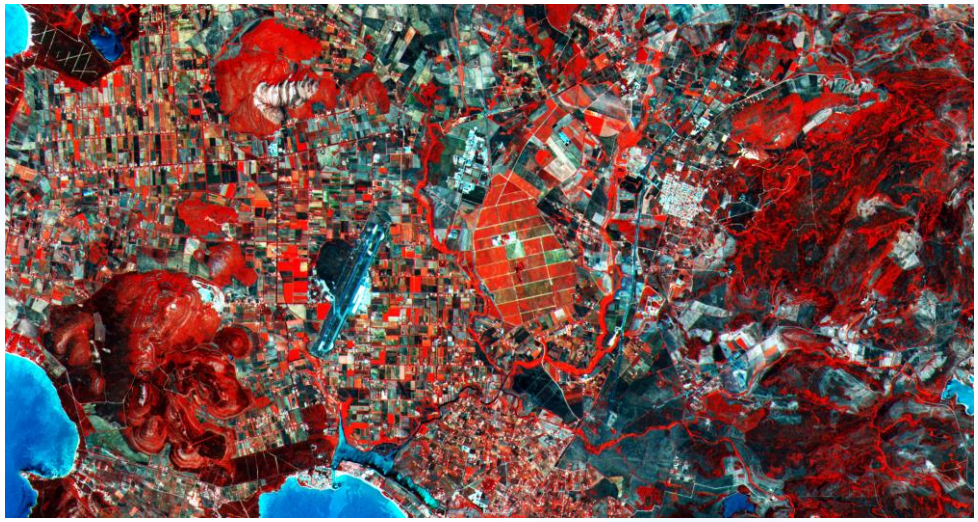
[c]Degraded Performance due to Scan Line Corrector failure in May 2003

Landsat Future – FY16 Budget Submit



Sentinel-2 – European Multi-Spectral Land Imaging

- Sentinel-2A launched successfully 23 June 2015
  - 13 spectral bands (Landsat-8 bands plus…) – ***NO THERMAL INFRARED***
  - 10 m resolution, 280 km swath – 10-day, single-satellite repeat
  - First imagery and processed products received 27 June 2015
  - Sentinel-2B on schedule for mid-2016 launch – 5-day system repeat

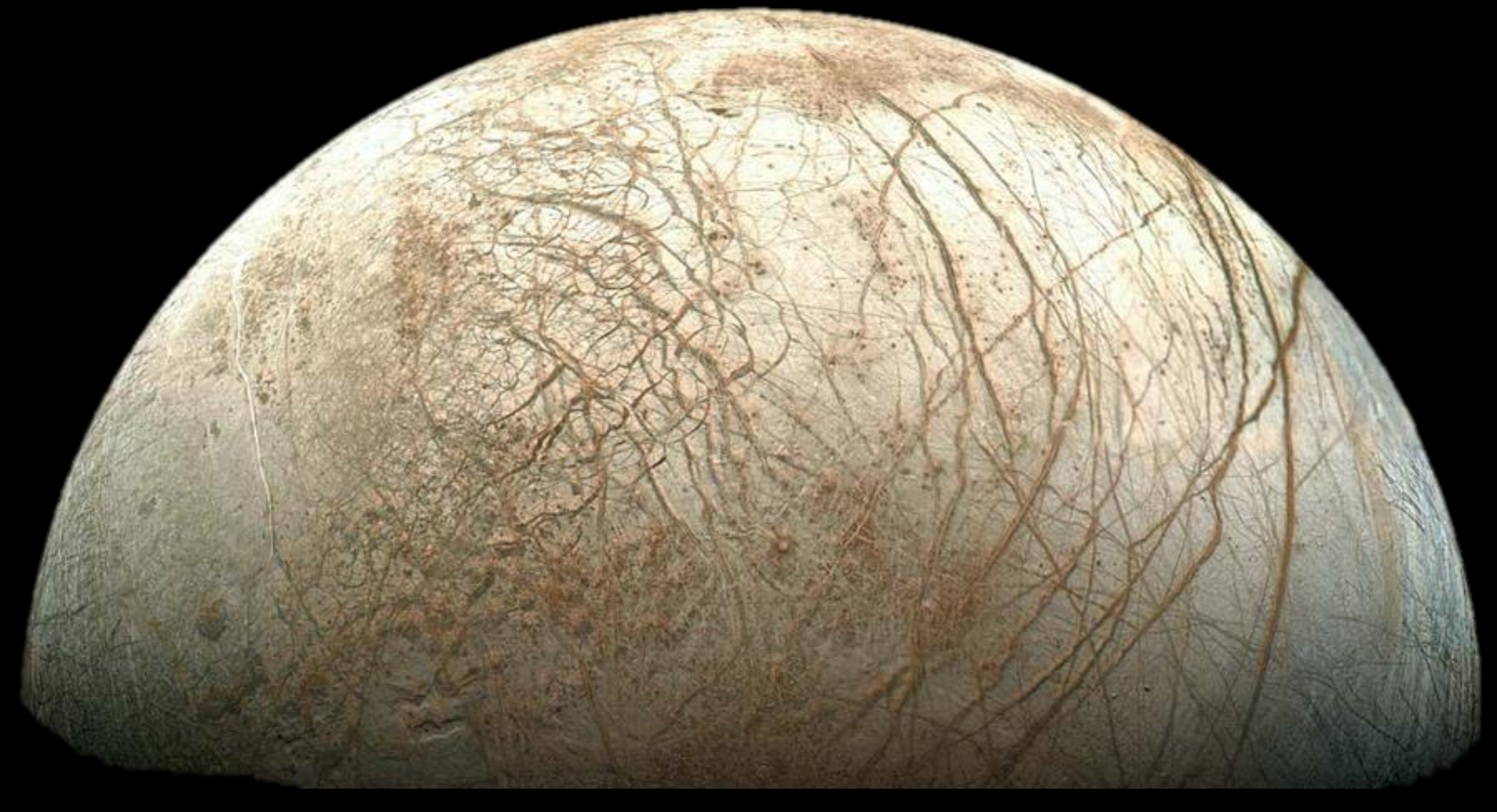


Northwest Sardinia

So. France, No. Italy

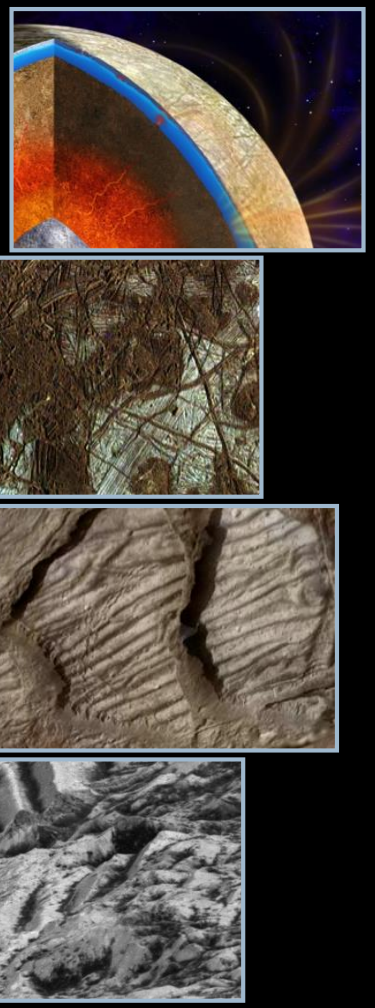
- **Open data availability agreement w/EU agreed: NASA, NOAA, USGS; State Dept. signs**
- NASA has solicited and selected research investigations for multi-system data fusion products

Planetary Science

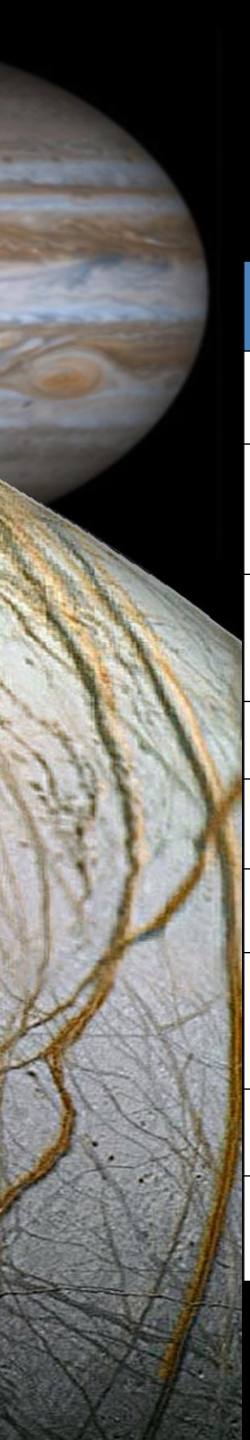


Europa Multi-Flyby Mission Science Goal & Objectives

- *Goal:* **Explore Europa to investigate its habitability**
- *Objectives:*
  - **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
  - **Composition:** Understand the habitability of Europa's ocean through composition and chemistry
  - **Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities
  - **Reconnaissance:** Characterize scientifically compelling sites, and hazards, for a potential future landed mission to Europa



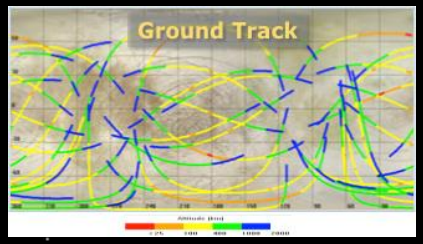
Overview of Selected Proposals

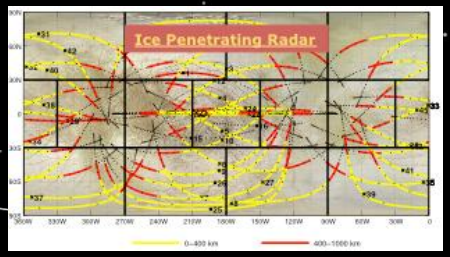


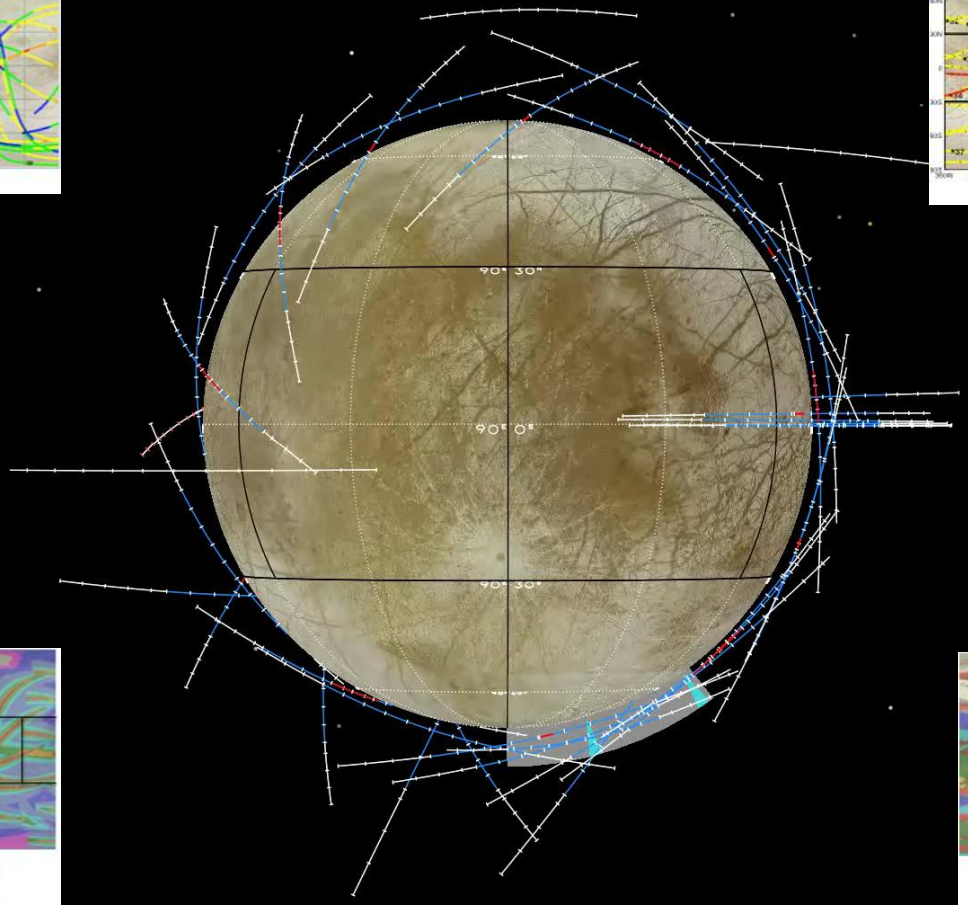
Instrument Type	Name	PI	Institution
Plasma	PIMS	Joseph Westlake	APL
Magnetometer	ICEMAG	Carol Raymond	JPL
Shortwave IR Spectrometer	MISE	Diana Blaney	JPL
Camera	EIS	Elizabeth Turtle	APL
Ice Penetrating Radar	REASON	Don Blankenship	Univ. Texas/JPL
Thermal Imager	E-THEMIS	Phil Christensen	ASU/Ball
Neutral Mass Spectrometer	MASPEX	Hunter Waite	SWRI
UV Spectrograph	E-UVS	Kurt Retherford	SWRI
Dust Analyzer	SUDA	Sascha Kempf	Univ. Colorado

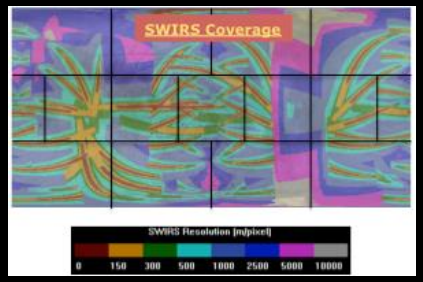
Europa Multi-Flyby Mission Coverage

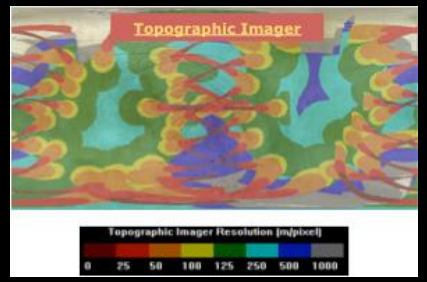
13F7-A21 Trajectory











- **Above 1,000 km → 2**
- 250 km to 750 km → 6
- 80 **km to 100 km → 9**
- 50 km → 18
- **25 km → 10**

Spacecraft Trajectory

$25 \text{ km} \le r_{alt} \le 50 \text{ km}$

$50 \text{ km} < r_{alt} \le 400 \text{ km}$

$400 \text{ km} < r_{alt} \le 1000 \text{ km}$

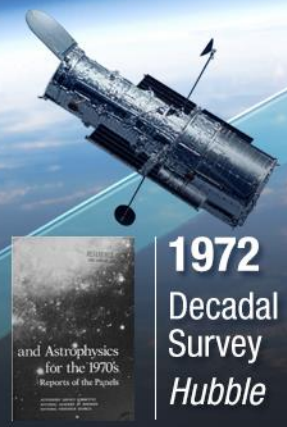
$1000 \text{ km} < r_{alt} \le 4000 \text{ km}$

National Aeronautics and Space Administration

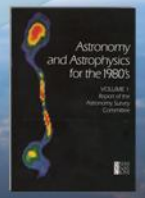
Astrophysics

ASTROPHYSICS

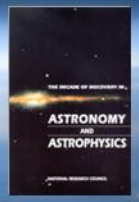
Decadal Survey Missions



1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST

JWST Hardware Status Updates

ISIM

- All instruments installed back into ISIM, vibration finished, acoustics test this month.

Optical Telescope Element (OTE)

- Deployable Tower Assembly installed into OTE backplane (center section, wings, backplane support fixture).
- OTE backplane preparing to ship to GSFC on August 24.
- 13 of 18 primary mirror segment assemblies shimmed for installation onto telescope backplane. All will be complete prior to arrival of backplane.

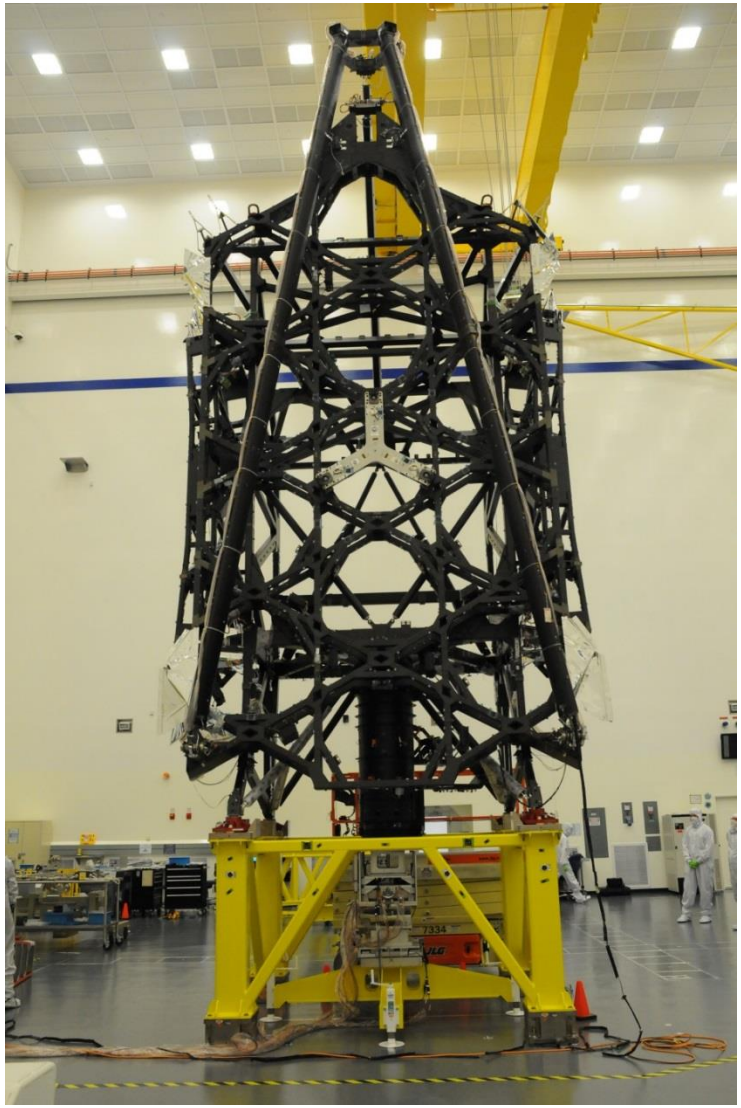
Spacecraft

- Spacecraft subsystems continue on track. Spacecraft structure completed and in testing.
- Sunshield layer 3 (delivered), 4, 5, and 2 in various stages of work.
- Cryocooler Compressor Assembly completed at NGAS, in final verification before shipping to JPL.

OTIS (OTE + ISIM)

- Optical Ground Support Equipment (OGSE) test #1 complete. All test objectives met, good practice for this Fall's OGSE #2 test.

Flight Telescope Progress



Backplane with Deployable Tower

Spacecraft Bus moving to test stand

Flight Cryocooler Compressor Assembly at NGAS

WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets

Coronagraph Technology Milestones		
1	Shaped Pupil mask fabricated with reflectivity of 10^{-4} and 20 μm pixel size.	7/21/14 ✓
2	Shaped Pupil Coronagraph demos 10^{-8} raw contrast with narrowband light.	9/30/14 ✓
3	PIAACMC mask fabricated with 10^{-8} raw contrast with 10% broadband light.	12/15/14 ✓
4	Hybrid Lyot Coronagraph demos 10^{-8} raw contrast with narrowband light..	2/28/15 ✓
5	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/15/15
6	Low Order Wavefront Sensing provides jitter sensing better than 0.4 mas rms.	9/30/15
7	Spectrograph read-out demo to have low dark current and read noise.	8/25/16
8	PIAACMC coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16
9	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16

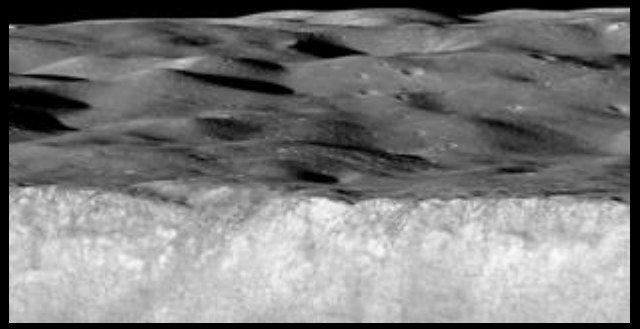
Widefield Detector Technology Milestones		
1	Produce, test, and analyze 2 candidate passivation techniques in banded arrays.	7/31/14 ✓
2	Produce, test, and analyze 1 additional candidate passivation techniques in banded arrays.	12/30/14 ✓
3	Produce, test, and analyze full arrays with operability > 95%.	9/15/15
4	Produce, test, and analyze final selected recipe in full arrays demonstrating a yield > 20% with operability > 95%.	9/15/16
5	Complete environmental testing of one sensor chip assembly, as per NASA test standards.	12/1/16

Preparing for the 2020 Decadal Survey
Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 Decadal Survey.
- **UV/Optical/IR Surveyor** –The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.

Pluto July 14, 2015

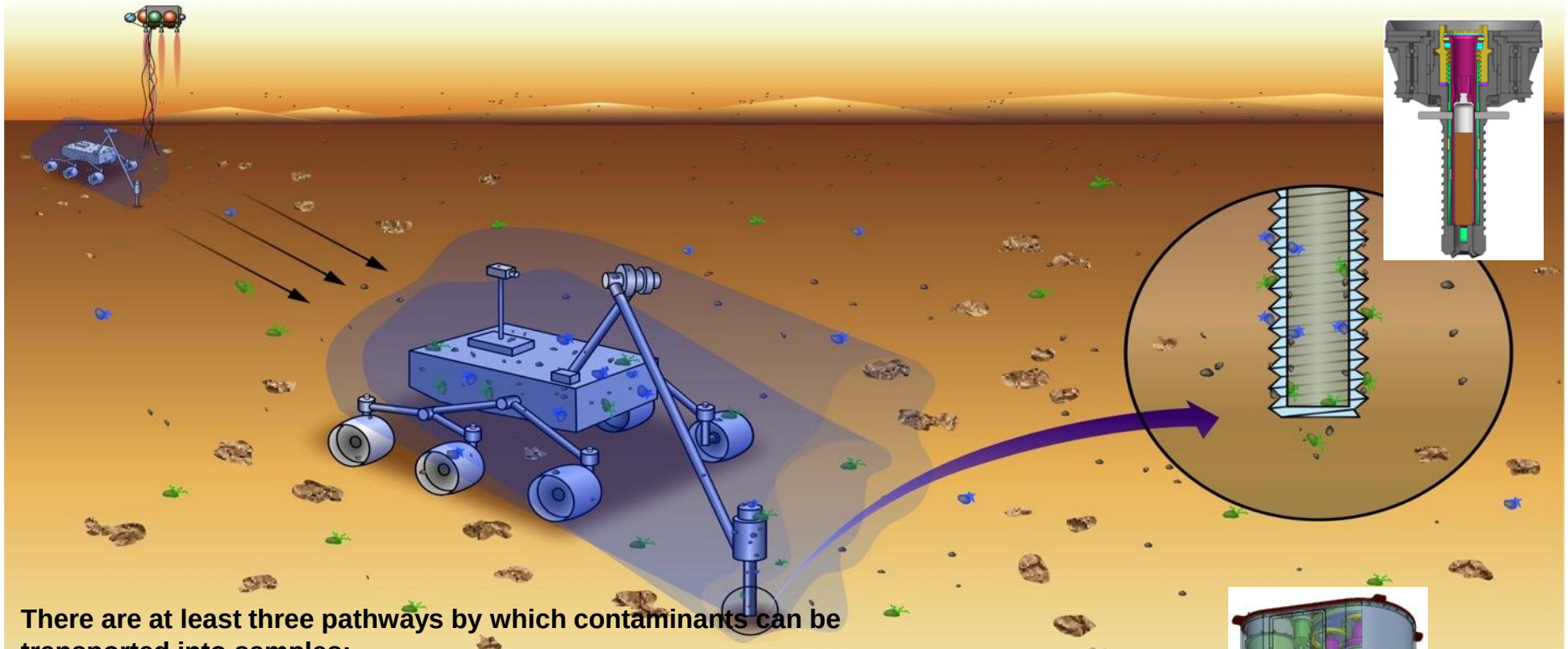


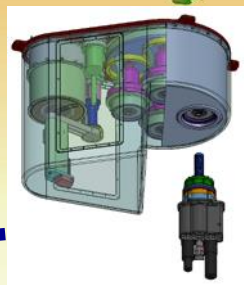
Selected Other Reports

Two-Step R&A Proposal Process

Planetary Protection Officer Report

M2020: Evolving Concepts for Sampling





There are at least three pathways by which contaminants can be transported into samples:

– Direct contact – microbial and molecular contaminants are transferred from the hardware surfaces to samples by direct contact.

– Particle transport – Microbes and molecular contaminant-containing particles are dislodged from spacecraft hardware surfaces by wind or by mechanical forces and are then carried by wind to the sampling ground or into the sample tube.

– VOC transport – outgassed volatile organic compounds from nonmetallic parts will diffuse or be carried by wind to condense on the sampling ground, sample contacting hardware, and samples.

Deposit cache or individual sample tubes

Curiosity Update

Jet Propulsion Laboratory

Mars Science Laboratory Project

Extended Mission Plans

Mars Science Laboratory: Mission to Mount Sharp

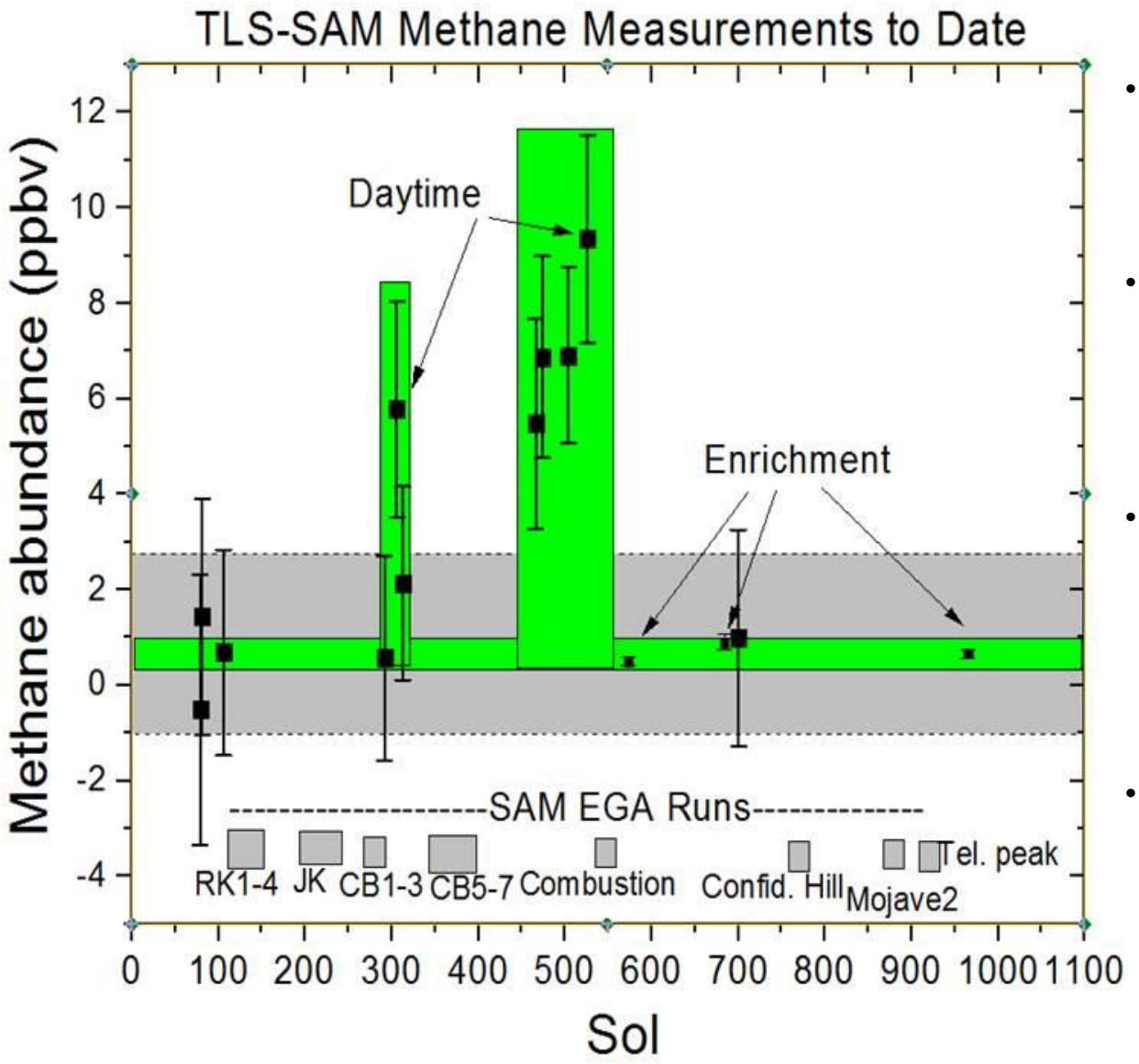
Sulfate Unit (8 km)

Clay Unit (6 km)

Hematite Ridge (5 km)

Murray Formation
(arrived Sept. 2014)

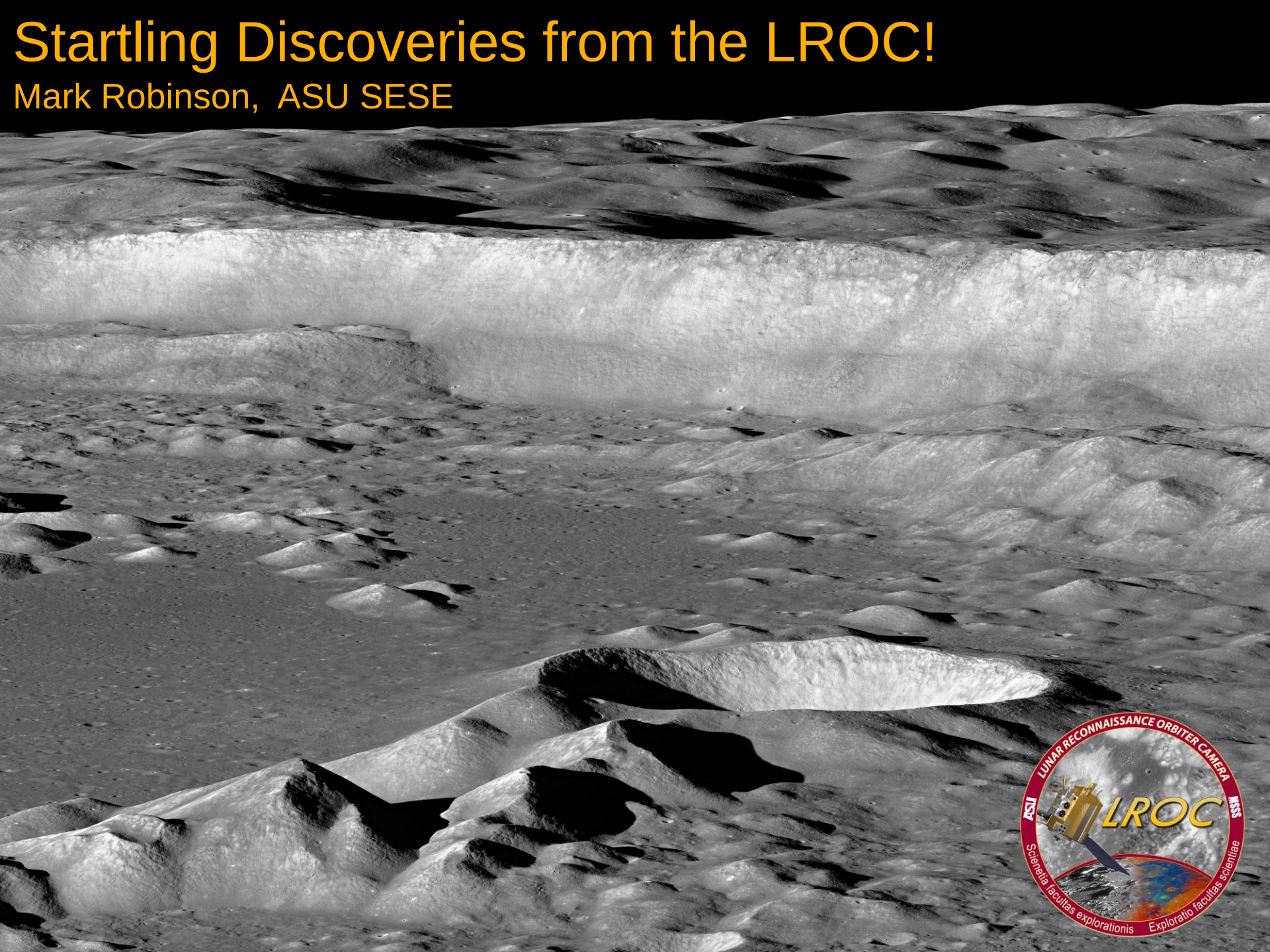
Ongoing Methane Measurements



- Curiosity detected a background methane abundance of 0.7 parts per billion (by volume)
- This background amount can be provided by UV degradation of interplanetary dust or carbonaceous chondrite materials
- A ten-fold enhancement that lasted about 60 sols is unexplained. It indicates active production of methane to the surface via a weak/local or strong/distant source.
- Curiosity will continue to monitor methane. If another enhancement is detected, the rate of sampling will increase to capture the evolution and loss.

Startling Discoveries from the LROC!

Mark Robinson, ASU SESE



Ongoing Tectonism

- Discovery of globally distributed population of 1-10 km scale low angle thrust faults (compression)
- Moon is still contracting (core freezes)
- Orientations of faults not random, evidence that Earth tides effect crustal stress patterns

- Ages <50 my
  - Smaller highland examples (10 m relief) expressed solely in regolith
  - Cross-cut 10 m scale craters
  - Associated back scarp graben (extension) 100 to 200 meters in length few meters deep

Small scale graben (image 692 m wide)

Watters et al, 2012, Nature Geosciences

Ad Hoc Big Data Task Force Challenges

- Definitions: “Big Data” means different things to different groups.
- Engineering: Architecture, infrastructure and logistics of storing/accessing/using large data sets
- Data rights: IT security, Intellectual Property
- Communication: Visualization, training

→How do we start asking the right questions to get the most out of big data?

→ What tools do we need? What tools do we have? What tools are being developed?

Task Force Membership

- Current Proposal – 10 seats
  - 1 Chair (Cyberinfrastructure specialization))
  - 1 Aero representative
  - 2 Industry reps
    - Have experience with NASA and use of big data for new science
    - Recommended by multiple sources
  - 6 Discipline representatives
    - Currently have 2 each from Earth Science and Heliophysics, 1 each from Astrophysics and Planetary Science

Goal is to hold the first Ad Hoc Big Data Task Force meeting in September 2015

Outline

- Science Results
- Programmatic Status
- **Findings & Recommendations**

SC Recommendation: Categorization for the Mars 2020 Mission

(Request Transmission to SMD AA)

Recommendation: At the June 2015 Planetary Protection Subcommittee meeting, the PPS heard presentations on the Mars Exploration Program (MEP) from its Director, James Watzin, and on the Mars 2020 mission from Deputy Project Manager Matt Wallace. Based on the mission description and the Mars 2020 project's stated goal to assemble a returnable cache of samples for possible future return to Earth, the mission should be given a Category V, restricted Earth return categorization.

Major Reasons for the Recommendation: All missions designed to return samples to Earth are Category V, which includes two subcategories – unrestricted Earth return, and restricted Earth return.

Current NASA policy dictates that sample return missions to Mars, Europa and Enceladus be Category V - restricted Earth return. Category V requirements are specific to the issue of ***backward*** contamination of Earth.

NASA policy dictates that these missions also meet all Category IVb requirements, addressing the ***forward*** contamination of Mars. Category IVb applies to Mars (and Europa and Enceladus) missions designed to investigate extant Martian life, but not designed to visit a Mars Special Region.

Consequences of No Action on the Recommendation: PPS has a statutory responsibility to recommend a planetary protection categorization for each NASA planetary mission.

SC Recommendation: Need for Planetary Protection process during surface operations

Recommendation:

The Planetary Protection Subcommittee recommends that NASA develop a process to react to unanticipated planetary protection issues as they arise during surface operations on current and future Mars surface exploration missions.

The Subcommittee suggests that NASA convene a Gale Crater “trailblazer” workshop to develop the process in the context of recent scientific discoveries made by the Curiosity team.

Major Reasons for the Recommendation:

Mars rovers, including Curiosity, have an operational requirement to meet planetary protection requirements during the course of surface operations. As an example, the Curiosity rover is restricted from coming in contact with a Mars Special Region. Science obtained during the mission may lead to the determination of a nearby Special Region that was not anticipated prior to launch.

SC Recommendation: Need for Planetary Protection process during surface operations (Cont.)

The PPS notes that operations on the Mars surface involve at least three stakeholders: the science teams, the operations teams, and the Planetary Protection Officer. In the view of the PPS, it may be difficult to develop a list of indicators, and a priori strategies, for dealing with unanticipated discoveries. The PPS therefore recommends that a **PP process** be developed for each mission, agreed to by all stakeholders. The process would serve to guide a **PP rapid response team**, including the PPO, the science teams and the operations teams with equal voices around the table.

The PPS suggests that NASA convene a **Gale Crater "trailblazer" workshop**, possibly with European counterparts, to review the science and continued plans for Curiosity operation, in view of the findings of frost, methane spikes and RSLs at Gale Crater.

Consequences of No Action on the Recommendation:

Future NASA science, particularly life detection efforts, may be compromised if unanticipated planetary protection concerns are not promptly addressed during surface exploration operations.

SC Recommendation: Use of Fueled Payload Adapter Fittings (PAFs)

Recommendation:

NASA should consider offering the use of fueled payload adapter fittings [PAFs] as part of their approved launch services, or alternatively enable use of such capabilities by the proposers.

Major Reasons for the Recommendation:

The use of fueled PAFs is currently not a standard launch option. Such an option could enable a wider range of low-cost missions, for example full Explorer missions that are within the Mission of Opportunity cost cap.

Consequences of No Action on the Recommendation:

A wide range of orbits at reduced costs to NASA would be unavailable if fueled PAFs are not utilized for new science.

Issue to Monitor: Heliophysics R&A Proposal Changes

Heliophysics Subcommittee Recommendation to SC

Recommendation: HPD should either increase the size of the grants to bring them more in line with their values of 30 years ago and/or reduce the number of pages from 15 to 10 or less for the Scientific/Technical/Management Section for R&A proposals.

Major Reasons for the Recommendation: For more than three decades, the basic size and scope of the H-SR & H-GI grants have remained the same: 15 page proposals for ~$125K/year for a duration of three years. The cumulative inflation index over the past 30 years is approximately a factor of 3.4; consequently at today's salary rates and grant funding level, a full time early career scientist currently needs more than two full grants to support his/her funding. This situation has led to the community and HPD spending an increasing amount of effort on writing and reviewing proposals for a decreasing amount of effective support. Larger awards and/or reduced page limits will ease the burden on the proposers and also allow each panelist to review more proposals. This could also result in smaller review panels and provide additional cost savings.

Consequences of No Action on the Recommendation: The proposal writing/reviewing process will continue to increase the burden on the community and the Discipline scientists.

SC understands the importance of this issue and directs Subc to research it further, taking into consideration the upcoming Astronomy and Astrophysics Advisory Committee (AAAC) report.